Road and Transportation Research Association
Working Group Transportation Planning

FGSV

RIN

Guidelines
for Integrated Network Design

Edition 2008 | Translation 2023

R 1

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These Guidelines were prepared in close consultation with the committee comprising members of Task Group 1.3.1 (Guidelines for Integrated Network Design), to which the following persons belonged:

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Preliminary remark:

The “Guidelines for Integrated Network Design”, edition 2008, replace the “Guidelines for the Design of Roads – Guidance for Functional Categorisation”, edition 1988. The translation was made possible by the German Federal Ministry for Digital and Transport (BMDV). The final editing was performed by Univ.-Prof. Dr.-Ing. Markus Friedrich, Stuttgart.

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1 Introduction

1.1 Purpose

The strategic development of transport networks is a component of spatial planning, i.e. of land use regulation, regional planning and urban planning. Spatial planning includes landscape planning, transport planning and other sectoral planning activities. The sectoral planning objectives are to be coordinated with those of the higher-level spatial planning and their often complex interactions are to be taken into account as early as in the planning phase.

The “Guidelines for Integrated Network Design” draw on the objectives of spatial planning and regional planning for the accessibility of central places and derive the functional categorisation of transport networks from the categorisation of central places. As a result, at the level of conceptual transport network design, the objectives for the development of transport systems are based on a uniform spatial planning approach thus supporting a coordinated transport network development.

In addition to the spatial planning approach to network design, the “Guidelines for Integrated Network Design” (German abbreviation: RIN) also incorporate environmental and landscape-related planning objectives. This involves considering the sensitivity of the environment surrounding the transport infrastructure in order to prevent or mitigate adverse impacts of the transport system while the transport networks are still at the conceptual planning stage. The RIN address the transport supply as a whole. They comprise the co-ordinated network development in each particular transport systems and the development of connections between the systems. This can strengthen the inherent advantages of one transport system and can combine their advantages with another transport system at transfer nodes. This supports the development of an optimal solution for the transport system as a whole.

1.2 Contents

The RIN address the design of transport networks including the public transport supply. This requires the following steps (figure 1):

1. **Functional categorisation of the transport networks (section 3):** A category is assigned to each network element of the transport network. This category results from the importance of the connections traversing the network element and the requirements of the environment surrounding the network element. The objective is to design the network elements of the transport network in a functional manner.
2. **Evaluating the service quality of connections (section 4):** For every connection, indicators describing the service quality are determined for each transport system or for a combination of transport systems. Comparing service quality indicators with quality levels allows to assess connections and thus identify “good” and “poor” connections.
3. **Quality requirements for the design of transport networks, network sections and transfer nodes (section 5):** The networks of specific transport systems have to meet requirements going beyond requirements of single network elements. The quality requirements on the level of connections and the category of the network elements determine the quality requirements of individual network sections.

Step 2 is necessary if, in the case of existing transport networks, the service quality of connections needs to be analysed and shortcomings localized. These shortcomings may provide a reason for planning measures to improve the network.

The RIN permit planners to incorporate not only the considered transport system but also other transport systems in the aforementioned steps. In this context, the importance of a specific network element may also be determined depending on the existing or already planned upgrade of another transport system. This also applies analogously to the quality requirements for connections or network sections that are finally determined by decision-makers.

The RIN provide a methodological aid to integrated network planning in which the relevant aspects of regional and environmental planning are included. This makes it possible to analyse and assess existing networks and develop network strategies for future transport networks. These steps influence

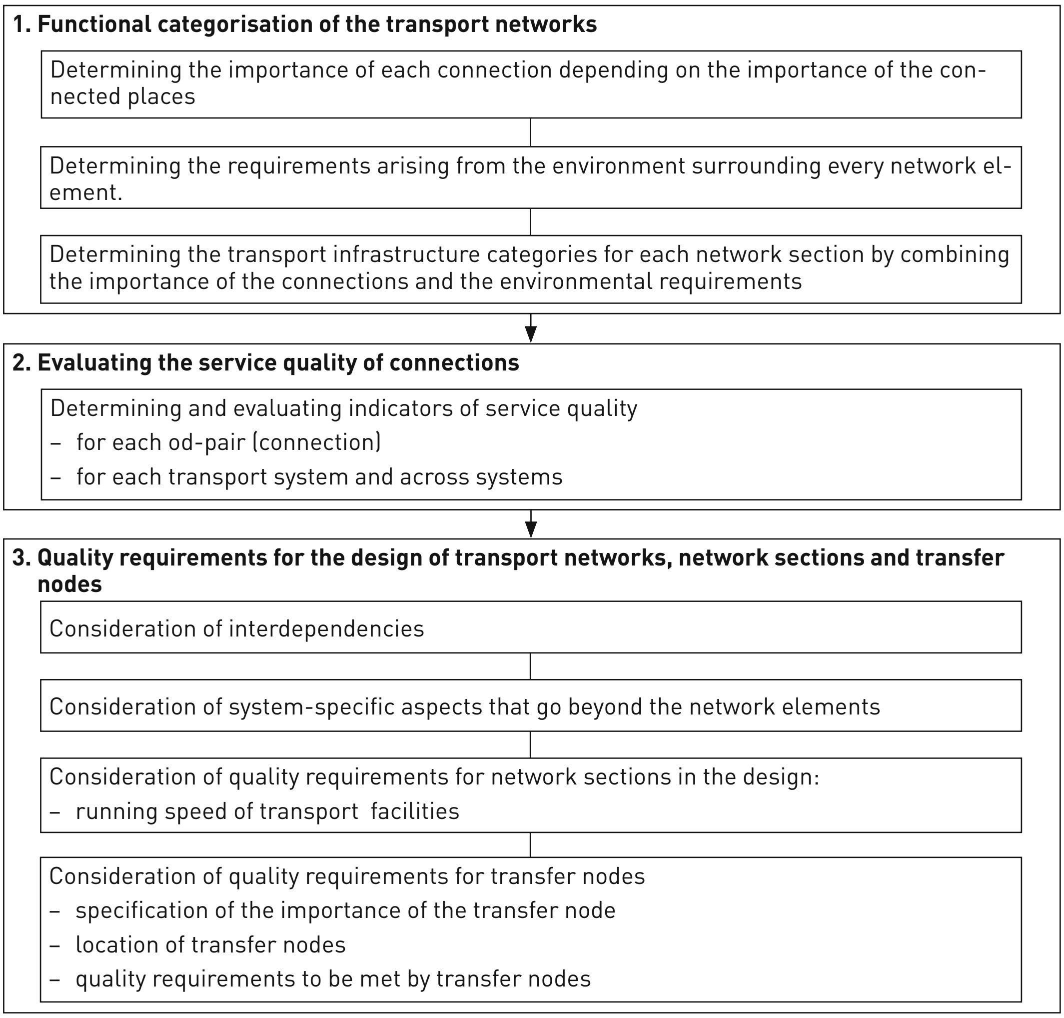


Fig. 1: Structure of the Guidelines for Integrated Network Design

- requirement plans (Federal Government, federal states);
- transport development plans;
- individual transport plans such as local transport plans;
- federal state development plans and spatial/regional plans.

The RIN do not assess the impacts of network strategies or individual measures. Here, reference is made to the relevant rules and regulation (figure 2) and procedures ("German Highway Capacity Manual", "Recommendations for the Safety Analysis of Road Networks", "Recommendations for Economic Feasibility Studies on Roads", "Standardized Appraisal in Local Public Transport" (Federal Ministry of Transport, Building and Housing, 2000), Macroeconomic Appraisal for the FTIP (Federal Ministry of Transport, Building and Housing, 2003), VDV Publication 4 (Association of German Transport Companies, 2001) and the Strategic Environmental Assessment (Federal Ministry of Transport, Building and Urban Development, 2006).

In the road sector, the functional categorisation of the RIN form the basis for the design and operation of roads, which are to be designed in accordance with the sets of design regulations ("Guidelines for the Design of Motorways", "Guidelines for the Design of Rural Roads", Directives for the Design of Urban Roads", "Recommendations for Public Transport Installations", "Recommendations for Cycle Traffic Installation" and "Recommendations for Pedestrian Traffic Installations": In the local public transport sector, VDV Publication 4 (VDV, 2001) contains more detailed guidance on the provision of transport services and regular-interval timetables.

Given the complexity of the interests affected, the RIN leave scope for discretion in terms of content and objectives. A deviation from the rules and requirements outlined below should always be made if the solution developed from the weighing-up process better satisfies the competing interests on the whole.

1.3 Scope of application

The Guidelines for Integrated Network Design address the following sectors of transport:

- motor vehicle traffic;
- local public transport (railways, undergrounds, trams, buses, etc.);
- cycling;
- pedestrian traffic.

In the sector of the road network, the functional categorisation applies to passenger and freight transport. On the other hand, evaluating the service quality of connections and the target values for the mean speed on the network sections are confined to passenger transport.

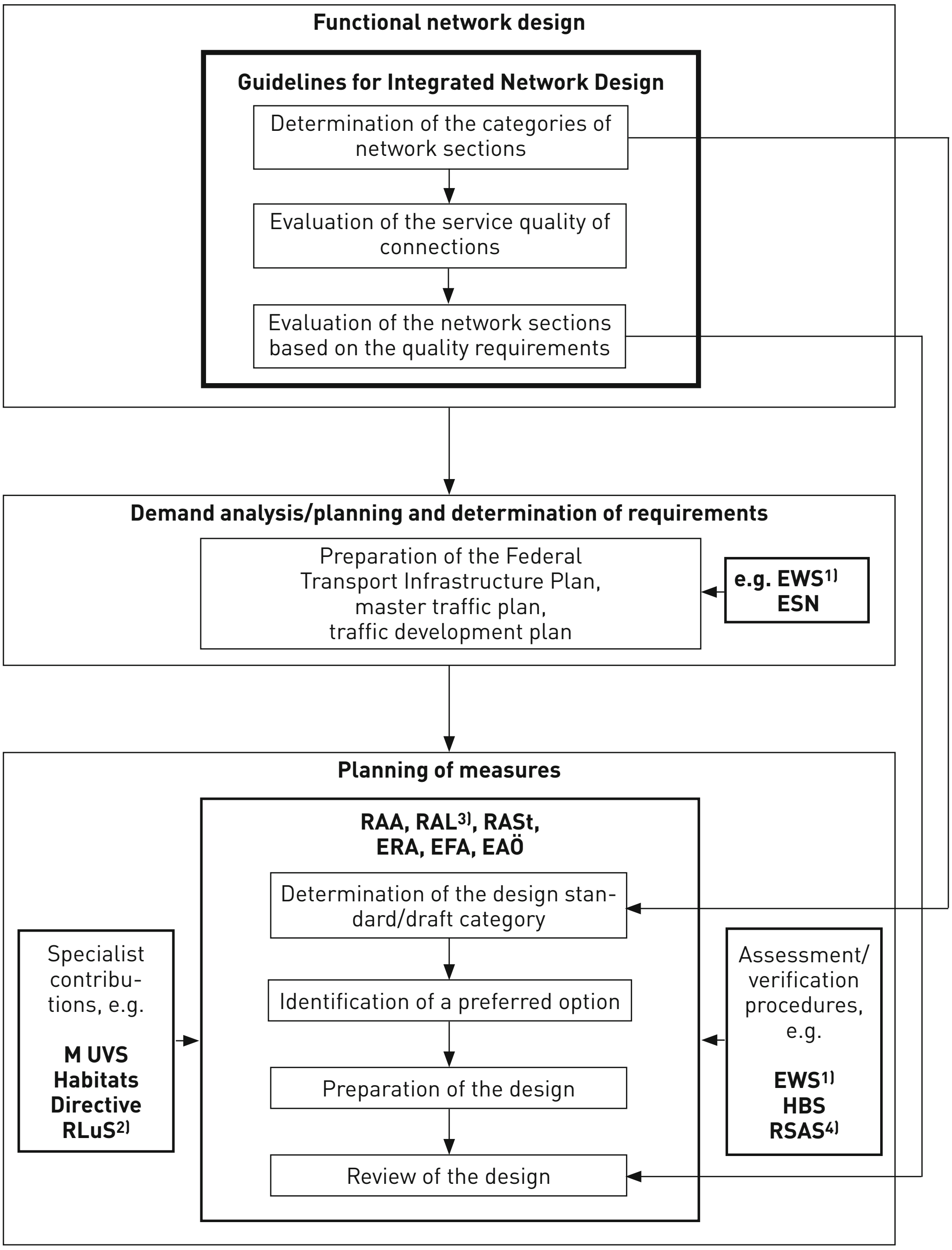


Fig. 2: Placement of the RIN in the overall structure of German guidelines

1) Withdrawn in the meantime
2) Published after the RIN, edition 2008, predecessor: MLuS
3) Published after the RIN, edition 2008, predecessor: RAS-L, edition 1995; RAS-Q, edition 1996
4) Published after the RIN, edition 2008, predecessor: ESAS

2 Principles of network design

The principles for the design of transport systems are derived from key socio-political values. This also applies to transport networks which, with their transport ways[1)] and transfer nodes, facilitate the accessibility of areas and their interconnectivity. Accessibility plays a role in determining how favourable the location of areas is and their opportunities for structural development as a residential and business location. In this context, the impact of the transport networks on competition between the regions has to be taken into account. Although transport systems cannot compensate for any location-related conditions, they can improve the accessibility of areas. Transport network planning is thus an instrument for supporting spatial and regional planning objectives. It can mitigate the obstacles to the development of areas, promote their development opportunities and also help to relieve the pressure on areas.

The objectives of spatial planning and transport network planning are closely interlinked through the system of central places. Transport networks support the central places in providing goods and services for their catchment area. At the same time, transport networks make it possible to exchange goods and services between central places within the meaning of an exchange function. Thus, transport networks strengthen the approach of "decentralized concentration" and the polycentric settlement system.

Transport network design is also to contribute to a more sustainable transport development. This is characterized by social acceptability, economic efficiency and ecological sustainability (FGSV, 2003).

The impact of transport networks on regional and urban development is associated with substantial costs for the general public. These costs relate to the following fields:

- transport costs;
- transport safety;
- environmental sustainability and
- investment and operating costs.

The objectives of spatial planning and transport network planning are, wherever possible, to be achieved at the lowest cost and with the fewest adverse impacts for the general public. Transport network planning should thus, as a matter of principle, adopt an integrative approach. In this context, integration covers the following aspects:

- **Integration of the planning disciplines:** this involves consolidating spatial planning, urban development, regional and land use planning, landscape planning and the promotion of economic development in transport planning. This is designed to support the settlement, spatial and economic development sought by regional planning and urban development, minimize adverse impacts on the landscape and the environment, consolidate traffic on high-capacity transport ways and make short distance trips possible in the interests of reducing traffic volumes.
- **Integration of the planning levels:** this involves dovetailing various planning levels – the European planning levels, the planning levels of the Federal Government, the federal states, the regions and the municipalities – within the framework of network design.
- **Integration of neighbouring planning areas:** this involves dovetailing the planning activities for certain areas with the activities of neighbouring areas and includes the identification of the impact of network design on neighbouring planning areas.
- **Integration of the transport systems:** this involves dovetailed planning of all transport networks and the establishment of cross-system links by providing transfer nodes. Integrated network design assesses the impacts of changes to one transport network on all transport systems, using the possibilities of coordination, functional augmentation and modal shift.

The aim of the functional categorisation of transport networks is to consolidate the travel demand in a manner appropriate for the tasks. This creates the general conditions for a network design that meets the requirements of transport and urban areas, has as little impact on the landscape as possible and ensures traffic safety. It thus makes a major contribution towards a sustainable traffic development (FGSV, 2003).

[1)] The term "transport way" is used in this document al the generic term for the infrastructure in a transport network regardless of the type of transport system (roadway, railway, waterway, cycleway, walkway). It corresponds to the German word "Verkehrsweg", which does not exit in the English language.

The task of the functional categorisation of the transport networks is to establish the standard categories for the planning, design and operation of the transport infrastructure. All further steps in designing network elements and transfer nodes are to take the functional categorisation of the network as their basis. It makes it possible to categorize individual network sections on the basis of their importance and the surrounding built and natural environment and, accordingly, to design them in a functional manner. Application of the functional categorisation may result in requirements for new construction, refurbishment and upgrading (including demolition). Action plans based on this are to be subjected to a value for money assessment. Local conditions are to be taken into account here.

3 Functional categorisation of transport networks

3.1 General

As part of the functional categorisation of transport networks, a specific category is allocated to each network section. This category results from the importance of the connections traversing the network elements of a network section. Depending on the transport system under consideration the category also considers the type of traffic, the type, location and surrounding environment of the transport infrastructure, including requirements of other transport systems using the network elements (figure 3).

Connectivity function levels (section 3.2) are used to differentiate the importance of connections. To differentiate the type of transport way and its interaction with the surrounding environment, the network sections are classified by category groups (section 3.4).

3.2 Importance of connections

3.2.1 System of central places

The system of central places forms the foundation for determining the importance of connections between municipalities (figure 4).

Depending on their importance from the perspective of spatial planning, municipalities are classified into central places of various levels and municipalities without central place functions. Central places are cities and towns, which, beyond the needs of their own population, are to supply goods and services for the population in their catchment area. They are preferred locations for public and private sector service providers and sites for industry, jobs and education. Municipalities without central place functions are dependent on the range of goods and services provided by the places with a central place function.

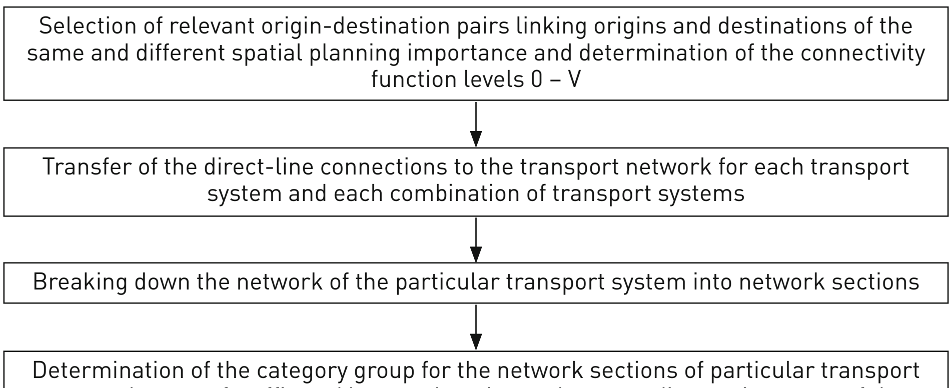


Fig. 3: Deriving the transport infrastructure categories from the functional categorisation

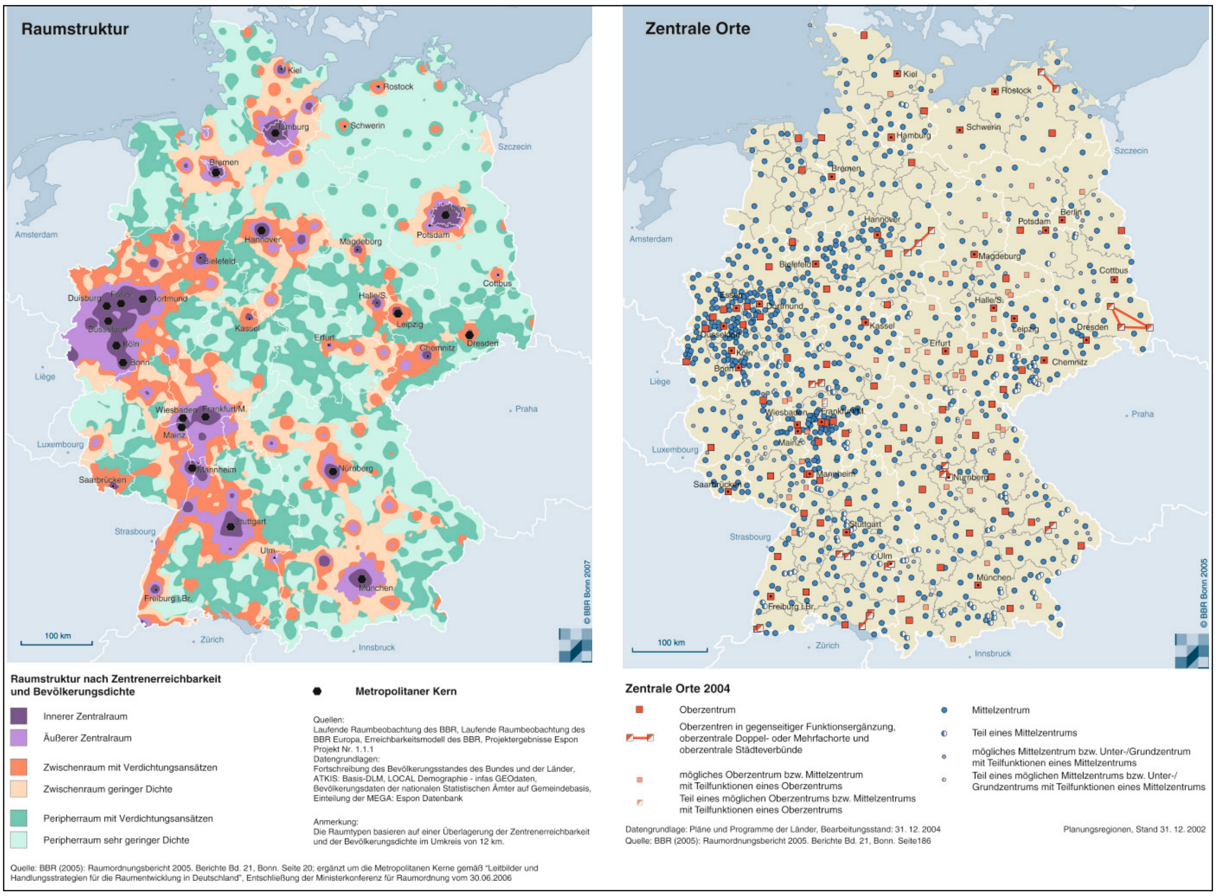


Fig. 4: Spatial structure with metropolitan regions and locations of higher-order and middle-order centres (Federal Office for Building and Regional Planning, 2005)

Depending on the importance of the central place functions of supplying goods and services and the size of the catchment area/zone of influence, the RIN distinguish various levels:

- metropolitan regions (MR) with an international or national zone of influence;
- higher-order centres (HOC) as administrative, supply, cultural and economic centres for the provision of higher-order goods and services;
- middle-order centres (MOC) as centres that meet upmarket requirements or less frequent specialized requirements and as hubs for trade, industry and services;
- lower-order centres (LOC) serve as centres for the provision of basic goods and services to meet the day-to-day requirements of their immediate sphere of influence.

All other municipalities are classified as municipalities without a central place function for determining the importance of links.

The principles of spatial planning call for, among other things, the spatial concentration of settlement activity on a system of high-performing central places as part of a decentralized settlement pattern (§ 2 (2)(2) of the Spatial Planning Act). The federal states fill the framework by drawing up spatial plans with which they classify, develop and promote their territory in accordance with his basic approach. Against this background, higher-order, middle-order, and lower-order centres are identified for each federal state in federal state development programmes and spatial/regional plans.

Central places of a higher level always also provide goods and services for the lower levels of centrality. For the design of transport networks, central places with some of the functions of a higher level of centrality are treated as centres without these functions. Dual centres or places that are part of a network of central places are usually treated as one central place. Here, one of the places is given the centrality level of the dual centre or association of central places, while the other places are assumed to be one level lower. Metropolitan regions with more than one core are treated in the same way as dual centres or parts of a central-place network of metropolitan cores.

In recent decades, there has been a process of gradual change in which metropolitan regions have emerged which, building on the polycentric urban system that has evolved over the course of time, mark a change in land use through increased global economic, social and cultural incorporation and are resulting in a change in the spatial structure (figure 4). These metropolitan regions, which were established as a spatial planning category for Germany by the Standing Conference of Ministers responsible for Spatial Planning in 1995, are major concentrations of industry and population at a European and global/continental level. For the RIN, the metropolitan regions are considered to be a spatial entity that may contain one or more metropolitan cores.

The connections between German and non-German metropolitan regions are of particular importance for international transport. They constitute the highest level of cross-border connections in the transport networks and also include connections for transit traffic through the Federal Republic of Germany. Beyond the central places, major transfer nodes between different transport systems are considered unless they are already covered by the central places. In passenger transport, this relates primarily to airports. For tourist regions of national importance and recreational areas of regional importance, decision-makers determine the level of central places to which these spatial entities are to correspond.

The Spatial Planning Act states that its guiding principle is to achieve a convergence of living standards in all regions. Table 1 contains specific targets for the time required to reach central places from places of residence, derived from requirements set out by the Standing Conference of Ministers responsible for Spatial Planning and based on this guiding principle. Table 2 contains targets for the time required to travel between central places of the same level of centrality.

The targets include access and egress times and apply to off-peak periods. Compliance with these targets is designed to ensure that the population is provided with central services on an area-wide basis. The trip time targets provide indications of possible spatial planning shortcomings or shortcomings in the provision of transport services. However, they do not constitute a separate quality criterion within the framework of network design in accordance with the approach of the RIN.

Table 1: Target values for the time required to reach central places from place of residence

Central place	Trip time in minutes	
	By car	By public transport
Lower-order centres	≤ 20	≤ 30
Middle-order centres	≤ 30	≤ 45
Higher-order centres	≤ 60	≤ 90

Table 2: Target values for the time required to reach central places from neighbouring central places of the same centrality level

Central place	Trip time in minutes to the nearest neighbour	
	By car	By public transport
Lower-order centres	≤ 25	≤ 40
Middle-order centres	≤ 45	≤ 65
Higher-order centres	≤ 120	≤ 150
Metropolitan regions	≤ 180	≤ 180

3.2.2 Centralities within municipalities

In towns and cities, connection between municipalities do not adequately describe the transport networks. Thus, for a functional categorisation, the connections between municipalities are to be supplemented by connections within municipalities.

The functional categorisation of connections within municipalities is derived from the importance of urban concentration areas with public sector institutions and important private sector institutions (services and retail trade).

Urban concentration areas can be classified on the basis of the following centralities within municipalities:
- major centre;
- district or local centre;
- neighbourhood centre and
- group of shops (lower-order centre).

These centralities within municipalities are allocated to the central places with regard to their transport importance in accordance with table 3. The major centre of a central place is normally classified one centrality level lower than the central place itself, because the major centre is of less importance than the central place in its entirety. Similarly, the district and local centres are classified one centrality level lower.

With this approach, a system of centralities within municipalities is established which, in terms of its transport importance, conforms to the system of central places.

Urban concentration areas can also be, for instance, discount stores and shopping centres, large corporations as well as event venues and recreational areas. Their transport importance is dependent on the size of the town or city and the local urban development intentions. The level of their centrality within municipalities is largely determined by local circumstances and established by the decision-makers. When considering networks in towns and cities, the first step is to portray the connections between central places. The second step involves adding the connections between the centralities within municipalities. Here, the continuations of the connections between municipalities to the centralities within municipalities as well as the connections between the centralities within municipalities are considered.

Table 3: Centralities within municipalities

Central place	**Centralities within municipalities**		
	Major centres	District or local centres	Neighbourhood centres
Higher-order centre	MOC	LOC	Mun
Middle-order centre	LOC	Mun	Mun

With this approach, the process of functional categorisation can also be applied to the transition zone between cities and their urban hinterland.

3.2.3 Connectivity function levels

To establish the importance of links, six connectivity function levels are defined (table 4 and figure 5). These connectivity function levels apply to all transport system to the extent that they are relevant to the transport system under consideration. The importance of a connection is a result of the importance of the centres that are linked. A distinction is made between connection that serve the supply function of a centre and connection that make possible an exchange between the centres.

Centralities within municipalities are to be included with the centrality level allocated to them (section 3.2.2) if level II connection or lower are to be determined. In most cases, they do not have to be considered until connectivity function level III.

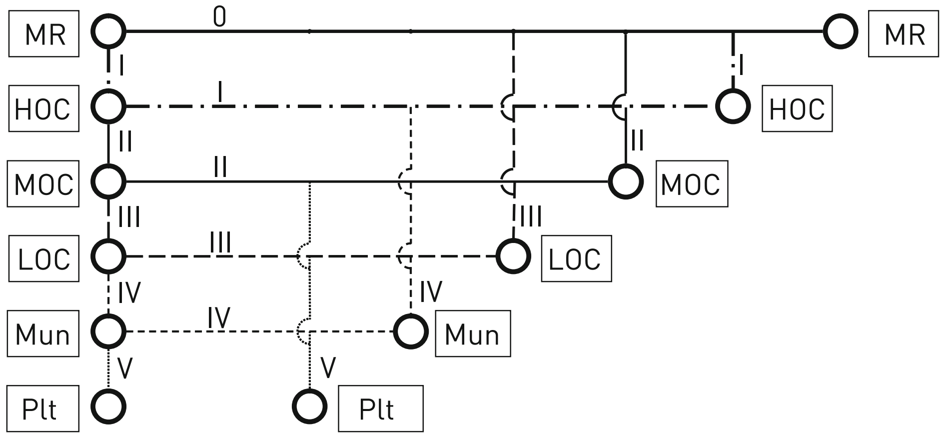
For each connectivity function level, the connections between the centres can be represented on direct-line networks. For the sake of clarity, graphic representations should be limited to neighbouring centres. When preparing the direct-line networks, the connections from one centre of a level to its nearest and second-nearest neighbouring centre of the same level are considered first (exchange function). Central places whose catchment areas are adjacent to one another are defined as neighbouring ("first ring"). Central places that exhibit a common neighbouring central place between them are defined as second-nearest neighbours ("second ring") (see also Annex A 1.1). In addition, connections with further neighbouring central places of the same level are considered if there is especially intensive transport interconnectivity with them. In the case of metropolitan regions, this can usually be assumed to be the case. Missing connections from centres of the levels under consideration to the neighbouring centres of the next higher level still have to be added (supply function).

When establishing a connectivity function level, the strength of the transport relationship between to centres may have an influence. Strongly pronounced transport interconnectivity or a high share of transit traffic may militate in favour of upgrading the connectivity function level resulting from spatial planning by one level. Less pronounced transport interconnectivity or an existing/planned good range of other transport systems may be reasons for downgrading the connection by one level.

Table 4: Connectivity function levels for connections

Connectivity function level		Categorisation criteria		Description
Level	Designation	Supply function	Exchange function	
0	Continental	–	MR – MR	Connection between metropolitan regions
I	Long-distance	HOC – MOC	HOC – HOC	Connection from higher-order centres to metropolitan regions and between higher-order centres
II	Interregional	MOC – HOC	MOC – MOC	Connection from middle-order centres to higher/order centres and between middle-order centres
III	Regional	LOC – MOC	LOC – LOC	Connection from lower-order centres to middle-order centres and between lower-order centres
IV	Local	Mun – LOC	Mun – Mun	Connection from municipalities/communities without a central place function to lower-order centres and Connection between municipalities/communities without a central place function
V	Vicinity	Plt – Mun	–	Connection from plots of land to municipalities/communities without a central place function

MR Metropolitan region
HOC Higher-order centre
MOC Middle-order centre, including middle-order centre within a municipality
LOC Lower and lowest-order centre, including lower-order centre within a municipality
Mun Municipality/communities without a central place function
Plt Plot of land
– Not applicable



MR Metropolitan region
HOC Higher-order centre
MOC Middle-order centre, including middle-order centre within a municipality
LOC Lower and lowest-order centre, including lower-order centre within a municipality
Mun Municipality/communities without a central place function
Plt Plot of land

Fig. 5: Connectivity function levels for connections and connecting links

3.3 Determination of the applicable connectivity function level

Taking the direct-line networks as a basis, the connectivity function levels for each transport system are assigned to the existing transport networks. This can also be done for suitable combinations of means of transport. Planned transport infrastructure can be included.

The direct-line networks are usually assigned to the transport network in two steps.

The first step is a computer-aided assignment with the help of traffic assignment models. This is generally based on the following criteria:

- directness of the connection (distance shortest path) or
- trip time (time shortest path).

The assignment should assume an almost free traffic flow which, taking into account all structural and traffic law circumstances, corresponds to the quality of service as defined by level "B" of the German Highway Capacity Manual. Additional guidance on the assignments to the road network can be found in Annex A 1.

When transferring the connectivity function levels, it is also necessary to reconcile the divergent objectives of a good service quality of connections, environmental protection and transport safety. The second step thus involves determining the extent to which the computed routes are suitable for the transport tasks resulting from the connectivity function level. This takes into account aspects such as:

- the bundling of travel demand,
- reducing traffic in built-up areas or other areas worthy of protection and
- usage of safe routes.

Regarding the traffic reduction in areas worthy of protection, reference is made to Annex A 1. To identify comparatively safe routes, it is recommended that a safety analysis in accordance with the Recommendations for the Safety Analysis of Road Networks be conducted.

Ultimately, decision-makers will select routes which, on the basis of their level of development and safety features, are suitable for the respective connectivity function level or are to be developed for it.

The connectivity function level between two central places is not allocated to the entire connection between the major centres of these places. Since the central places have a spatial dimension and the urban concentrations are not located exclusively in the major centre but are distributed within the central place, a connectivity function level is allocated only up to the edge of the place to be linked. The subsequent network elements are given a lower connectivity function level (see Annex A 1.3 for more details on the categorisation of connections at the edge of places).

At the edge of places, the changeover to a lower connectivity function level normally takes place at nodes on the transport network at which the traffic flows related to the central place divide into different connections to reach various facilities and amenities of the central place.

Figure 5 shows how connections with a lower connectivity function level are connected to transport ways with higher connectivity function levels and continued on these.

When transferring the connectivity function levels of direct-line networks to the existing or planned transport networks, targeted support can be given to the development potential inherent in a transport system. Thus, the connectivity function level of one link in a transport system can be upgraded or downgraded compared with another transport system. To promote the seamless use of several transport systems, the connectivity function levels should be routed via a uniform system of transfer nodes.

When allocating the direct-line connections of cycling to existing or planned networks, separate routes should be determined for utility cycling and cycle tourism if the route that is more attractive for tourists is not also the shortest or fastest route.

As a result of the allocation, the different connectivity function levels overlap on the existing or planned network elements with varying frequency. If two or more connectivity function levels overlap on one network element, its categorisation is generally based on the higher connectivity function level. A deviation from this is possible if there is insufficient travel demand between the central places for this level or if the higher connectivity function is largely provided by other transport systems. If different connectivity function levels result along a transport way (sequence of network elements), it may be advisable, depending on the network context, to determine a uniform connectivity function level.

3.4 Categories of transport ways

3.4.1 Categories of transport ways for motor vehicle traffic

On transport routes for motor vehicle traffic within built-up areas, the connectivity function overlaps with the access and residential amenity functions. There are competing uses between the functions. This is all the more problematic the more pronounced the claims on land use from the link, access and residential amenity function coincide in one section. In such cases, the transport network design is to either seek to separate the functions or find solutions in which none of the functions is unreasonably impaired by the others.

Transport ways for motor vehicle traffic are distinguished section-by-section on the basis of the following characteristics:

– motorway/rural road/urban road,
– outside built-up areas/on the fringe of built-up areas/within built-up areas,
– without/with adjacent development and
– arterial road/access road.

A network section is considered to be within a built-up area if the adjacent development appears continuous to the road user. This is usually the case if the buildings abutting the road are less than 50 m away from the road over at least one half of the section (sum of both directions).

A network section is considered to be on the fringe of a built-up area if the road user interprets the development as being scattered. This is usually the case if the road is closely linked to the rest of the road network because of the development.

On the basis of these characteristics, five groups of categories for motor vehicle traffic transport ways are defined (figure 6).

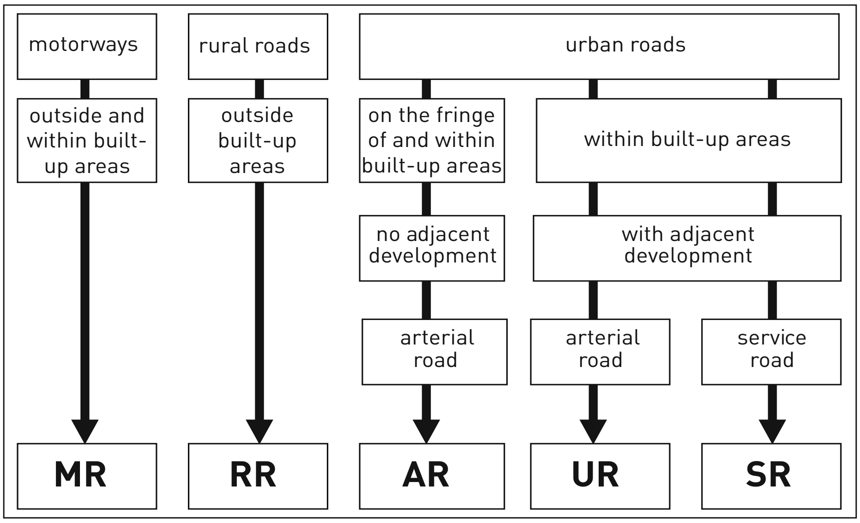


Fig. 6: Groups of categories of transport ways for motor vehicle traffic

Category group MR (motorways) comprises dual carriageways without adjacent development and with grade-separated and partially grade-separated junctions outside, on the fringes of and within built-up areas, which may be used exclusively by high-speed motor vehicle traffic. Access is only possible via special junctions. They are mainly roads signposted with sign 330 of the German Road Traffic Regulations (motorways) and with blue direction signage. However, they also include dual-carriageway near motorway standard roads with grade-separated junctions signposted with sign 331 of the German Road Traffic Regulations (motor road) and usually with yellow direction signage, or sometimes with white direction signage in the case of urban motorways. In the case of urban motorways the speed limit is 80 km/h or 100 km/h. Roads of this category are usually federal roads or state roads.

Category group RR (rural roads) comprises single-carriageway roads without adjacent development outside built-up areas. This also includes short dual-carriageway sections along otherwise single-carriageway roads. They are generally connected to roads of the same category group by at-grade or grade-separated junctions.

These roads are predominantly intended for use by general traffic, although in special cases they can be designated motor roads by means of sign 331 of the German Road Traffic Regulations. The speed limit is usually 100 km/h or lower. Roads of this category may be federal roads, state roads, district roads or municipality roads. These roads perform primarily a connecting function. In the case of individual buildings directly abutting the road they may also perform an access function to a small extent. If there are frequent access movements as a result of lengthy roadside development, it may be appropriate to allocate the section to category group AR.

Category group AR (major arterial roads without adjacent development) comprises roads without adjacent development on the fringes of or within built-up areas. These roads perform primarily connecting functions. On the fringes of built-up areas, they are a continuation of category group RR roads as they approach larger continuous built-up areas. The roadside environments are frequently characterized by scattered development with tertiary-use facilities. For this reason, the access function of these roads is low. These roads are single or dual carriageways. They are connected to the rest of the road network predominantly by at-grade signal controlled junctions or roundabouts. The speed limit is usually 70 km/h on the fringes of built-up areas and usually 50 km/h within built-up areas. Roads of this category may be federal roads, state roads, district roads or municipality roads.

Category group UR (major urban arterial roads with adjacent development) comprises roads with adjacent development[2] within built-up areas whose main purpose is to provide connections or to collect traffic from access roads. They are also used by public transport line routes. They can also be components of connections between municipalities (roads passing through centres of towns). These roads are designed as single or dual carriageways. They are generally connected to roads of the same category group by at-grade signal controlled junctions or roundabouts. Since the adjacent development is accessed directly from the road, these roads are characterized by spaces for parking. The speed limit is usually 50 km/h or lower. Roads of this category may be federal roads, state roads, district roads or municipality roads.

Category group SR (access or service roads) comprises roads with adjacent development within built-up areas whose main purpose is to provide direct access to the adjacent developed land or to provide space for amenity functions. In addition, these roads provide access to urban quarters characterized by housing, business and services. These roads are almost always single carriageways and are connected to one another by at-grade non-signal controlled junctions. They are connected to category group UR roads by at-grade signal controlled or non-signal controlled junctions or roundabouts. In special cases, they are used by public transport line routes. They carry a sizeable proportion of local cycle traffic. This is one of the main reasons why the speed limit is 30 km/h in many cases. Roads of this category are usually municipality roads.

Table 5: Transport way categories derived from category groups and connectivity function level for motor vehicle traffic

Connectivity function level \ Category group		Motorway	Rural roads	Arterial roads without adjacent development	Arterial roads with adjacent development	Roads serving developments
		MR	**RR**	**AR**	**UR**	**SR**
Continental	**0**	**MR 0**	(shaded)	–	–	–
Long-distance	**I**	**MR I**	**RR I**	(shaded)	–	–
Interregional	**II**	**MR II**	**RR II**	**AR II**	(shaded)	–
Regional	**III**	–	**RR III**	**AR III**	**UR III**	(shaded)
Local	**IV**	–	**RR IV**	–	**UR IV**	**SR IV**
Vicinity	**V**	–	**RR V**	–	–	**SR V**

MR I	Designation of category
(shaded)	Problematic because of conflicts arising from functional overlaps
–	Non-occurring or not applicable

[2] Also transport ways that do not yet have but are suitable for adjacent development.

Table 6: Designation of categories of transport ways for motor vehicle traffic

Category group		Category	Designation
MR	Motorways	MR 0/I	Long-distance motorway
		MR II	Interregional motorway, urban motorway
RR	Rural roads	RR I	Trunk road
		RR II	Interregional road
		RR III	Regional road
		RR IV	Local road
		RR V	Access road
AR	Arterial roads without adjacent development	AR II	Urban through road, arterial road without adjacent development
		AR III	Urban through road, arterial road without adjacent development
UR	Arterial roads with adjacent development	UR III	Urban through road, arterial road within built-up areas
		UR IV	Urban through road, arterial road within built-up areas
SR	roads serving developments	UR IV	Collector road
		UR V	Residential road

The **category of a transport way for motor vehicle traffic** relates to a network section on the road network. In accordance with table 5, it is produced by combining the

- connectivity function level (0 to V) and the
- category group (MR, RR, AR, UR, SR).

Table 6 identifies the categories of transport ways for motor vehicle traffic that are likely to provide satisfactory solutions from a structural and operational point of view. It is true that, in everyday practice, there are also other categories of transport way for motor vehicle traffic. However, there are frequently serious conflicts between their land-use requirements for transport and non-transport purposes, and resolving these conflicts by means of design measures is possible only rarely and only with a great deal of effort and expenditure.

3.4.2 Categories of transport ways for public transport

Transport ways for public transport are combinations of the network infrastructure and the public transport line routes.

The network infrastructure for public transport comprises railways and roads. The roads used by public buses are mostly shared with motor vehicle traffic. Railways can be distinguished in heavy rail for passenger and freight trains and in urban light rail, which comprises underground railways, light rail systems and trams.

A distinction is made between the following types of network infrastructure:

Separate infrastructure or tracks which, because of their location or design, are routed separately from other traffic. In the case of rail systems, the separate tracks also include the level crossings.

Special infrastructure or tracks located in the roadspace of public roads but separated from other traffic by kerbstones, protective devices, hedges, lines of trees or other fixed barriers. In the case of rail systems, the special tracks also include at-grade junctions.

Embedded infrastructure or tracks that share the road with motor vehicle traffic or are guided through pedestrian zones. These also include infrastructure separated from other traffic by markings only and almost all infrastructure used by bus routes.

As a result of the different density of settlement within municipalities and across municipal boundaries, the distances between stops/stations varies and there are different maximum operating speeds, resulting in different running speeds. Thus, for local transport, a distinction is made on the basis of the location of the infrastructure relative to the built-up area.

The network infrastructure for public transport is used by scheduled services operating with fixed timetables. The components of the operating scheme are:

- vehicles and number of vehicle units,
- running speeds,
- operating form and
- timetable.

The characteristics of the transport ways for public transport are essentially determined by the form of operation, which in turn is determined by the location and type of infrastructure.

Thus, for transport network planning, the category groups of transport ways for public transport are derived from:

- the type of transport (long-distance or regional),
- the type of infrastructure (independent, partly independent, embedded) and
- the location (within or outside built-up areas)

as shown in figure 7.

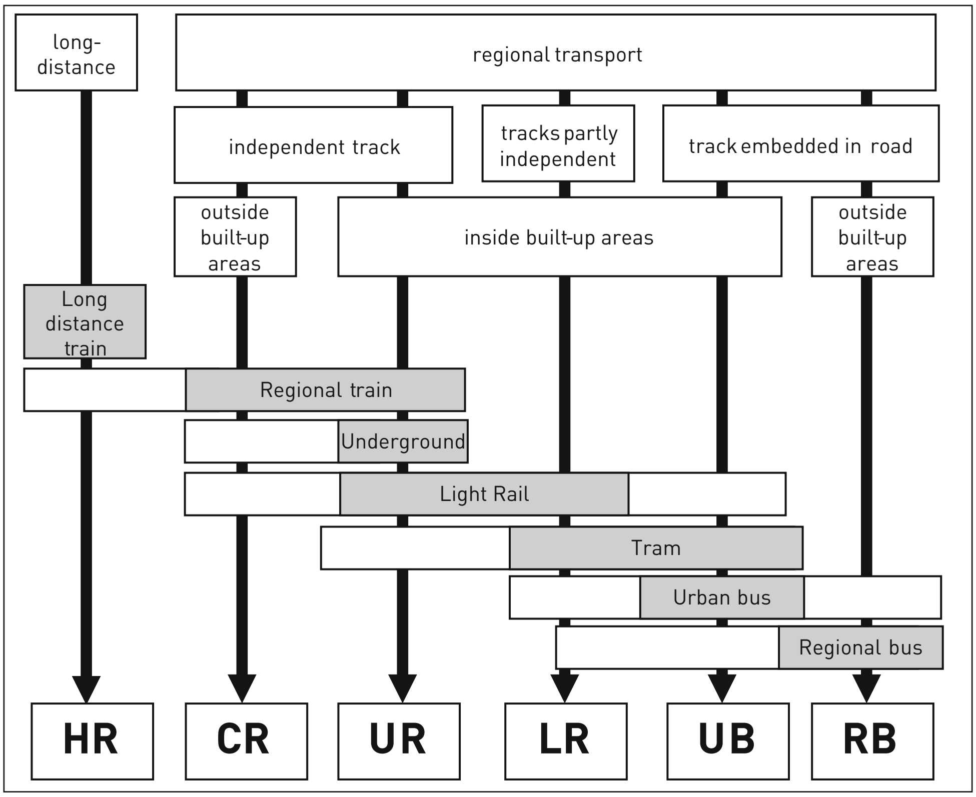


Fig. 7: Groups of categories of transport ways in public transport

Category group HR (long-distance railway, heavy rail) comprises primarily timetabled long-distance passenger rail services. Trains run on separate tracks either exclusively with trains of the same type or in mixed traffic with local passenger trains and freight trains. Category group FB is usually routed into town and city centres.

Category group CR (local railway, commuter rail) comprises timetabled local passenger rail services outside built-up areas. Trains run on separate tracks usually in mixed traffic with long-distance passenger trains and freight trains. Category NB also includes rapid transit systems, light rail systems and underground railways outside built-up areas.

Category group UR (separate railway, underground rail) comprises timetabled underground railway, rapid transit and local passenger rail services within built-up areas. Category UB also includes timetabled light rail services on separate tracks within built-up areas.

Category group LR (light rail) comprises timetabled light rail and tram services within built-up areas if they run on special tracks. At road junctions, the vehicles are subject to the traffic lights controlling road traffic. In most cases, however, public transport is given priority.

Category group UB (urban tram/bus) comprises timetabled tram and light rail services on embedded infrastructure plus bus routes with built-up areas.

Category group RB (regional bus) comprises timetabled regional bus services on road infrastructure outside built-up areas.

The **category of a transport way for public transport** relates to a network section on the transport network. In accordance with table 7, it is produced by combining the

– connectivity function level (0 to V) and the
– category group (HR, CR, UR, LR, UB, RB).

Table 8 shows the categories of transport way for public transport that are likely to provide satisfactory solutions from a structural and operational point of view.

Table 7: Transport way categories derived from category groups and connectivity function level for public transport

Category group / Connectivity function level		Long-distance traffic	Regional transport				
			Independent track		Track partly independent	Track embedded in road	
			Outside built-up areas	Inside built-up areas			Outside built-up areas
		HR	**CR**	**UR**	**LR**	**UB**	**RB**
Continental	**0**	**HR 0**					
Long-distance	**I**	**HR I**	**CR I**				
Interregional	**II**		**CR II**	**UR II**	**LR II**	**UB II**	**RB II**
Regional	**III**		**CR III**	**UR III**	**LR III**	**UB III**	**RB III**
Local	**IV**				**LR IV**	**UB IV**	**RB IV**

Table 8: Designation of categories of transport ways for public transport

HR	Mainline railway	HR 0	Continental mainline passenger rail services
		HR I	Long-distance mainline passenger rail services
CR	Regional railway outside built-up areas	CR I	Long-distance passenger rail services
		CR II	Interregional passenger rail services
		CR III	Regional passenger rail services
UR	Separate railway	UR II	Local passenger rail services, underground and light rail as a primary connection
		UR III	Local passenger rail services, underground and light rail as a secondary connection
LR	Light rail	LR II	Light rail and tram as a primary connection
		LR III	Light rail and tram as a secondary connection
		LR IV	Light rail and tram to provide access
UB	Tram/urban bus	UB II	Tram and bus as a primary connection
		UB III	Tram and bus as a secondary connection
		UB IV	Tram and bus to provide access
RB	Regional bus outside built-up areas	RB II	Interregional bus services
		RB III	Regional bus services
		RB IV	Local bus services

3.4.3 Categories of transport ways for cycling

Transport routes for daily cycling (trip purposes work, education, leisure, , shopping) have to meet primarily requirements resulting from the connecting and access functions.

Transport ways for cycle tourism have to meet special requirements resulting from their amenity value.

Transport ways for cycling are distinguished by two category groups:

Category group OC comprises transport ways for cycling outside built-up areas. They run on the carriageways of the roads or alongside the roads or on separate cycle tracks.

Category group IC comprises transport ways for cycling within built-up areas. They run on the carriageways of the roads or alongside the roads or on separate cycle tracks. They provide primarily local and short-distance connections. However, they also include network sections of interregional connections within built-up areas.

The **category of a transport way for cycling** relates to a network section on the cycle network. In accordance with table 9, it is produced by combining the

- connectivity function level (II to V) and the
- category group (OC/IC).

Table 10 identifies the categories of transport ways for cycling.

Table 9: Link matrix for the derivation of categories of transport ways for cycling

Connectivity function level \ Category group		Outside built-up areas	Within built-up areas
		OC	**IC**
Interregional	**II**	**OC II**	**IC II**
Regional	**III**	**OC III**	**IC III**
Local	**IV**	**OC IV**	**IC IV**
Short-distance	**V**	**–**	**IC IV**

Table 10: Designation of categories of transport ways for cycling

Category group		Category	Designation
OC	Outside built-up areas	OC II	Interregional cycling connection
		OC III	Regional cycling connection
		OC IV	Local cycling connection
IC	Within built-up areas	IC II	Cycling highway connection within a municipality
		IC III	Main cycling connection within a municipality
		IC IV	Cycling connection within a municipality
		IC V	Cycling access within a municipality

3.4.4 Categories of transport ways for pedestrian traffic

Transport ways for pedestrian traffic provide connecting, access and amenity functions. They are distinguished by two category groups:

Category group OP comprises transport ways for pedestrian traffic outside built-up areas that are used primarily for recreational pedestrian traffic (hiking). The principal factors determining the design of these sections are the requirements arising from leisure traffic. Their use is characterized predominantly by local structures.

Category group IP comprises transport ways for pedestrian traffic within built-up areas that are used primarily by everyday pedestrian traffic (footways). They provide predominantly local and short-distance connections. The principal factors determining the design of these transport routes are generally the requirements arising from the access function. Footways leading to and from major destinations (for instance stations, city centres) also meet the requirements resulting from the connectivity function.

Category IP also includes pedestrian traffic facilities whose primary function is to provide opportunities for people to linger in the public realm, to go shopping and to play games. In this case, the principal factors determining the design are the requirements arising from the amenity function.

In the case of transport ways for pedestrian traffic, no distinction is made on the basis of the importance of the link. Thus, the **categories of a transport way for pedestrian traffic** result directly from category groups OP and IP.

4 Evaluating the service quality of connections

4.1 General

A functional design of transport networks can be achieved if the transport way categories described in section 3 are used to assign quality requirements defined in section 5 to each section of the transport networks.

It is advisable to conduct a problem analysis before developing a transport network plan. In the integrated planning of transport networks for motor vehicle traffic and public transport, the options for developing one transport system can be explored in relation to other transport systems.

In the problem analysis, the services qualities of connections are compared with suitable quality requirements. In this context, the target values for the individual network sections, which are defined in section 5, should be considered. Deviations from the quality requirements indicate shortcomings in the network that may result from missing or congested network sections.

An analysis of the service quality on connection-level provides information for extending, upgrading and converting existing transport networks. Network plans developed in this way should be evaluated on connection-level to document the improvements. This step does not replace an economic feasibility study which is usually required for construction, conversion and upgrade schemes.

The services quality on connection-level are analysed using relevant criteria and associated indicators. The analysis determines indicator values which are then graded using evaluation functions.

The following section introduces a set of relevant criteria and the associated indicators for the analysis of the services qualities of connections and describes methods for determining the indicator values. All the criteria are confined to the perspective of the users.

The RIN does not provide quality requirements which are generally valid for the selected criteria. It is the responsibility of the decision-makers to determine a desirable quality level. In addition, the currently available data does not provide a sufficient basis for estimating representative evaluation functions. Instead, Annex A 2 uses the example of selected connections to illustrate a methodology for deriving level of service values for an existing network. The suggested evaluation functions can be taken as a benchmark for an assessment of existing networks. The decision-makers must determine which service level is acceptable and should serve as target for network design.

4.2 Criteria and indicators for the services quality

Relevant criteria for describing the service quality of services are the time required, directness, safety, travel costs, reliability and comfort. Additional criteria in the case of public transport are the temporal availability of services and, in the case of non-motorized transport, the physical effort of a movement. Although the inclusion of all criteria in the planning process is desirable, only the criteria and associated indicators shown in table 11 are used in the following.

Table 11: Criteria and indicators for describing the service quality of connections

Criterion	Indicator
Time required	– Direct speed – Trip time ratio
Directness	– Detour factor – Number of transfers

From a user perspective, the crucial criterion for describing the service quality of connections is the time required. The indicator “direct speed”, which is used to quantify the criterion “time required”, takes account of the fact that there are significant differences in the distances between central places. These requires a transformation of the target values for travel times presented in tables 1 and 2 into speeds. The quality levels set out in Annex 2 are based on the target values listed in tables 1 and 2. However, these time targets do not constitute a separate indicator for the evaluation of the service quality of a connection.

When directly comparing car and public transport, the indicator “trip time ratio” can be used as an additional indictor quantifying the criterion “time required”.

The “directness” criterion only serves as a supplementary criterion, if the “time required” criterion shows a poor service level. The indicators “detour factor” and “number of transfers” can then explain the reasons for a poor service level for the direct speed.

The inclusion of a “safety” criterion is desirable, but until now there is no sufficiently knowledge concerning the safety level of particular network elements.

Likewise there are no sufficient foundation for an evaluation of the criteria “costs”, “reliability” including transfer reliability in public transport and “comfort”.

It is difficult to establish values for evaluating of trip costs, because they are mainly determined by general socio-political settings.

The “reliability” criterion describes the ability to reach a destination on schedule. It can be quantified, for instance, by the total minutes of delay or by the distribution of the trip time of a connection over an observation. The description of reliability requires the availability of continuous measurements of trip times, which are not yet generally available.

Comfort is less a feature of an entire connection but rather a characteristic of the means of transport used and of the interchanges between the means of transport.

Regarding the temporal availability of public transport, reference is made to existing criteria for the assessment of standards in public transport, which contain recommendations for catchment areas of stops, headways and service frequencies (e.g. VDV 2001, Bavarian Ministry 1998, Hessian Ministry 1998, FGSV, 2001).

4.3 Identification of indicators values

When identifying the service quality, indicators values are determined for every examined connection. For existing networks, the indicator values can be identified by test runs, with modelling calculations or by using route planners and timetable information systems. The indicators are identified for each connection separately for every transport systems (e.g. car, public transport) or for combinations of these transport systems (e.g. Park & Ride). As a rule, the connections to the nearest and second-nearest neighbour centres are examined for each connectivity function level.

Annex 2 contains further guidance on the analysis of the service quality of connections.

4.4 Assessment of the indicators

The indicators identified for each connection are classified using six levels of service (table 12). By using a uniform appraisal scale, this approach improves the comparability of different indicators, illustrates the relevance of any given indicator to the specific application, makes it easier for decision-makers to perform the task of stipulating quality requirements for the service quality and makes the impact of their decisions more transparent.

The levels of the service dependent on the direct-distance. This considers the fact that the requirements for the quality of service change with the distance. As the distance increases, the speed requirements increase, but the acceptable number of transfers increases.

Table 12 Levels of service (LOS)

LOS	Description
A	Very good quality
B	Good quality
C	Satisfactory quality
D	Acceptable quality
E	Poor quality
F	Unacceptable quality

4.5 The criterion "time required"

A traveller wishing to move from one point to another chooses a route that appears favourable and also – if they have sufficient time at their disposal – a point of departure that is suitable. If the course of a route between two points on the network is known, it is possible to calculate indicators that describe the "time required" criterion for the connection.

When describing the time required, the distinctive features of private transport and public transport have to be taken into account. To calculate the time required in public transport, the travel times laid down in the timetable, including transfer waiting time, are used. In car traffic, the time required can vary because of individual driving styles and changing traffic conditions. To calculate the time required in private transport, either travel times in the off-peak periods or travel times in the peak periods or a combinations can be used, depending on the question. In all cases, any disruption caused by road works sites and random incidents (for instance accidents) should not be taken into account. Use of the travel times in the off-peak periods is appropriate if the purpose is to answer the question as to whether a suitable connection is available on the network for reaching a central place. Use of the travel times in the peak periods is appropriate if the purpose is to answer the question as to whether such a connection is adequately dimensioned to meet the traffic demand. When classifying the indicators in quality levels, it is advisable to use different levels of requirements for the two questions. The time required is quantified using the "direct speed" and "trip time ratio" indicators, which are derived from the trip time.

The trip time comprises the time required to move from an origin address to a destination address. It thus consists of the following components:

- Access time:
  time spent walking from the origin address to the point at which the traveller gets into their car or onto the public transport vehicle.
- Waiting time:
  time spent waiting at the public transport stop of origin.
- Ride time:
  time required for the trip between getting into the vehicle and getting out of the vehicle. In public transport and in combinations of transport systems (e.g. Park & Ride), the ride time may include time required for transfers and, in car traffic, the intermediate stops required at junctions and the time spent looking for a parking space.
- Egress time:
  time spent walking between getting out of the vehicle and reaching the destination address

The **direct speed** is the result of the quotient of direct distance and trip time. It implicitly takes into account the distance covered and is thus suitable for a comparison of the time required between connections of different distances.

Within the scope of integrated network design, the qualities of services of competing transport systems should be compared using the **trip time ratio**. The main focus here is on a comparison between car and public transport, although hybrid forms (Park & Ride) and, within built-up areas, cycling (including Bike & Ride) can also be included.

Annex A 2.2 suggests benchmark values for the assessment of the direct speed. Annex A 2.3 contains benchmark values for the trip time ratio.

4.6 The “directness” criterion

In the case of connections with a poor categorisation of the “time required” criterion, directness can be used as a supplementary criterion. In car traffic and public transport, directness is described using the “detour factor” indicator. For public transport, the “number of transfers” indicator is also used.

The **detour factor** is defined as the quotient of the trip length and the direct distance between the origin and destination. Its importance increases with the distance between the connected places and with the connectivity function level.

A high amount of time required combined with an acceptable detour factor indicates too low running speeds in the transport network, which it may be improved by means of capacity enhancing upgrades. If, on the other hand, there is a high amount of time required combined with a high detour factor, consideration should be given to whether an augmentation of the transport network by creating new, more direct connections or compacting the system of central places is appropriate.

Annex 2.4 contains benchmark values for the assessment of the detour factor.

The **number of transfers** is given by the mean number of times a traveller has to change vehicles (change of means of transport) to move from one point to another. Such changes of means of transport occur not only within public transport but also when changing from a car to public transport. The indicator values of the number of transfers are not confined to whole-number values. Real numbers may result if the number of transfers varies in the course of the day or if both a direct trip and a quicker trip with transfers are available simultaneously.

The number of transfers includes all transfers during a door-to-door trip to move from one point to another (excluding the initial boarding and final alighting).This means that, a long-distance trip also includes transfers in required travel to and from the mainline stations.

Annex 2.5 contains benchmark values for the assessment of number of transfers in public transport (including Park & Ride).

5 Quality requirements for the design of transport networks, network sections and transfer nodes

5.1 General

Transport users use a sequence of network elements to move from one point to another. Objectives regarding the service quality of connections thus lead to requirements for the quality of the network elements and for the quality of the transport supply on a network section. A network section is composed of several network elements of one category (a connectivity function level and a category group). The service quality of connections can be improved mainly by measures on the level of network elements.

Transfer nodes are places where travellers change between different transport systems, especially to public transport. The service quality of public transport connections is thus also determined by the design of the transfer nodes.

5.2 Network for motor vehicle transport

Roads outside built-up areas predominantly perform connecting functions for private motorized transport. They are also used by cyclists and public transport.

Roads outside built-up areas shall perform their spatial planning function with a high level of road safety and an appropriate quality of traffic flow. They shall conserve natural resources, they shall be integrated into the surrounding environment as far as possible and shall use valuable land only to a small extent. They are to be routed at an adequate distance from environmentally sensitive areas and have as little adverse impact as possible on the requirements of the surrounding built environment.

For reasons of road safety and traffic quality, roads outside built-up areas are, wherever possible, to be designed such that they can be used by private motorized transport at a steady speed appropriate to the category.

In order to illustrate the various network functions to the road user, there are different design categories for roads outside built-up areas. The purpose of this is to give the user route characteristics that are as uniform and distinctive as possible for each category. This shall reduce unexpected situations that may result in accidents.

At the points where roads outside built-up areas become roads within built-up areas, the categories have to be dovetailed. access and amenity purposes

Roads within built-up areas not only connect central places within municipalities but also offer access functions and provide space for amenity functions. For this reason, the impacts of motorized traffic on the surrounding environment are to be mitigated as far as possible by ensuring that the roads fit in well with urban design. Since roads within built-up areas are used jointly by motorized and non-motorized traffic, measures are necessary to promote the compatibility of the road users.

Modifications to the road network by means of construction, upgrading or conversion schemes are to be considered if:

- major transport bottlenecks are to be removed,
- obvious safety shortcomings are to beresolved , or
- significant pressure on the built environment is to be mitigated.

It should be examined whether the environment-related impacts of a planned scheme are justifiable, induced motor traffic is low (FGSV 2005) and shifts from public transport are acceptable.

Construction or upgrading schemes shall, wherever possible, avoid statutorily protected sites, open spaces of ecological importance or areas used for recreation. When selecting an alignment, the protection purposes related to open spaces are to be taken into account. If, for reasons of overriding importance, the use or severance of open spaces that are of ecological importance and/or important for countryside-related recreation is unavoidable, the procedures provided for this purpose are to be conducted (for instance Environmental Impact Assessment [EIA]). In some cases, the demolition of road sections might also be a possibility (IGS, 2001).

Road planning that affects public transport or rail freight installations shall take account of the interests of these transport systems. This includes – for instance when selecting road cross sections or junctions – making technical arrangements for an acceleration of public transport, safe solutions at railway crossings that are cost-effective for the authorities responsible for road construction and maintenance and for rail operators and, in the case of a railway line running parallel to a road, the retention of an option for upgrading or, in the case of disused railway lines with potentially high demand, reopening of the track.

Planning for public transport ways affecting road facilities shall consider the interests of private motor vehicle traffic. This requires, for instance when designing and constructing embedded track, ensuring that the remaining roadspace makes it possible for motorized and non-motorized road users to drive safely in a smooth traffic flow.

Roads with a higher level of connecting importance generally traverse a larger number of network elements. For reasons of road safety, continuity principles apply outside built-up areas. The promotion of road characteristics that are as uniform as possible is thus all the more important the higher the connecting importance is.

When roads pass through built-up area, this results in a significant rupture in their design characteristics, For this reason, roads of connectivity function level I should, for reasons of safety and to relieve the pressure on the built environment, not pass through built-up areas wherever possible. In the case of roads of connectivity function level II, it is to be examined – depending on the local situation (high level of traffic, high level of heavy goods vehicle traffic, high share of interregional traffic, intensive use of the road passing through the built-up area for access and amenity purposes) – whether a bypass is advisable or whether other measures (for instance modification of the road passing through the built-up area, shifting through traffic to other roads, improving the range of services provided by alternative transport systems) are more appropriate.

Measures to change the network are justified if a benefit-cost assessment demonstrates that the total benefit for society as a whole is higher than the costs of the authority responsible for construction and maintenance (construction and maintenance costs) Such a measure is all the more efficient the higher the benefit-cost ratio (BCR) is. At the same time, it should be examined whether the objectives being pursued with the measure can be achieved more economically and in a more environmentally acceptable manner by taking measures in other sectors, for instance in the development of settlement patterns or in other transport systems.

Transport network design shall design the individual connections in such a way that – in keeping with the spatial planning objective of good accessibility – the network elements provide a certain service quality. Thus, for the design and sizing of network elements, targets for an appropriate quality of traffic are defined, depending on the route category.

Table 13 contains target values for the mean car speeds on network sections in the peak period according to the German Highway Capacity Manual. These speeds also include the necessary waiting times at junctions.

In the case of roads outside built-up areas, the target speed is also determined by the distance range relevant for the connectivity function level. If the relevant distance is toward the upper end of the standard distance range, the higher values should generally be aimed for, if the relevant distance is towards the lower end, the lower values will suffice.

In the case of roads and road sections within built-up areas, it is necessary, when establishing the target car speed, to find a balance between the requirements arising from the connectivity function level and the requirements of the environment surrounding the road (access and amenity functions).

The target car speed forms a requirement for the design of a road under the current design regulations. This target is used, within the scope of the highway engineering design in accordance with the German Highway Capacity Manual, to compare the speeds achievable on streets of houses.

The determination of a target value does not replace the need to analyse the impacts of a planned measure to improve the network and to conduct a benefit-cost assessment to prove the feasibility of such a measure.

Table 13: Category of transport ways for motor vehicle transport and mean target car speeds

Category group		Category		Standard distance range [km]	Target passenger car speeds [km/h]	
MR	Motorways	MR 0/I	Long-distance motorway	40 – 500	100 – 120	
		MR II	Interregional motorway, urban motorway	10 – 70	70 – 90	
RR	Rural roads	RR I	Trunk road	40 – 160	80 – 90	
		RR II	Interregional road	10 – 70	70 – 80	
		RR III	Regional road	5 – 35	60 – 70	
		RR IV	Local road	Up to 15	50 – 60	
		RR V	Access road	–	None	
AR	Arterial roads without adjacent development	AR II	Urban through road, arterial road without adjacent development	–	on the fringe of build-up areas	50 – 60
					within build-up areas	40 – 50
		AR III	Urban through road, arterial road without adjacent development	–	on the fringe of build-up areas	40 – 50
					within build-up areas	30 – 40
UR	Arterial roads with adjacent development	UR III	Urban through road, arterial road within built-up areas	–	20 – 30	
		UR IV	Urban through road, arterial road within built-up areas	–	15 – 25	
SR	roads serving developments	UR IV	Collector road	–	None	
		UR V	Residential road	–	None	

5.3 Network for public transport

5.3.1 General

Integrated transport network design should explore the possibilities for developing the transport system by shaping the quality of services in public transport and motor vehicle transport. This is designed to strengthen the competitive position of public transport and promote the intermodal use of both transport systems.

By integrating spatial and transport planning, public transport should be systematically strengthened by means of concentrated settlement development around the stops. The design of the public transport network should, as a matter of principle, seek a balance between the positive and negative impacts of construction and upgrading schemes.

5.3.2 Features of the transport network

Public transport comprises long-distance and local passenger rail services, underground, rapid transit and light rail services, tram services and scheduled bus services Public transport also includes demand-responsive transport (dial-a-bus and shared-use taxis) or local ship and ferry services operated on a scheduled basis.

Public transport as a whole is to be developed and operated as an integrated transport system. In this system, the various means of public transport are interlinked structurally and operationally and have integrated fares and ticketing. Public transport services should be operate with a regular headway, ideally with a system headway, i.e. a basic headway valid for all lines.. A public transport suplly with a system headway enjoys high user acceptance on trips that involve transfers. Further information can be found in the " Fact Sheet for public transport timetables with system headways" (FGSV, 2001).

Railways are generally considered to be more favourable in terms of the quality of services, but are not suitable for many transport tasks for economic reasons. They have the advantage that, by running on separate or special tracks, they achieve significantly higher running speeds than road-based means of transport and thus represent a good alternative to private motorized transport in integrated transport network planning. High traffic volumes enable frequent services with high-capacity public transport lines. This is especially true for urban rapid rail transit systems in metropolitan regions. Hub-and-spoke systems should be served by adapted scheduled services At the same time, these systems should avoid unnecessary competition from parallel public transport services andline routes with large detours. Here, a suitable solution has to be sought between the economic necessities of providing transport services and attractive service qualities on the level of connections.

In areas with a low level of demand for transport, public transport services can often only be operated as basic services as part of a public service obligation. For such areas, demand responsive transport comprising dial-a-bus systems or shared taxis can complement scheduled services in a meaningful manner. Likewise, in these areas, local public transport is frequently developed to a considerable extent from the transport of schoolchildren. The timetabled services established for this purpose should, wherever possible, be included an integrated public transport network. Here, a balance has to be sought between the obligations arising from the transport of schoolchildren and the financial possibilities of the public transport authorities.

5.3.3 Features of the transport services

Public transport networks consist of the road and railway infrastructure and the scheduled services provided by the public transport vehicles.

The stops[3] determine the area covered by the transport services. A small number of stops in an area with large catchment areas requires long access/egress times and reduces the connection quality. Correspondingly, a large number of stops with small catchment areas result improve the connection quality. Nevertheless, an optimum must be sought with regard to access/egress time and travel time. For economic reasons, areas with high demand can be served by small catchment areas. In areas with a lower demand, larger catchment areas are reasonable.

Users are more likely to accept larger catchment areas if the stops provide good connection qualities. Accordingly, a larger catchment area is accepted for long-distance services than for local services, and the catchment area of stops on regional, underground or rapid transit railway lines is larger than at bus or tram stops.

For any given catchment area around the stops, the scheduled services provide the public transport supply.

Scheduled services consist of pre-determined stop sequences and a fixed timetable. Public transport connections result from combining one or more scheduled services.

Public transport timetables provide,

– the service frequency provided during the period of operation and
– the running speeds.

The transport supply is defined by the number of scheduled services within a unit of time. A high number, i.e. a high service frequency, improves the temporal availability of the transport supply and thus the service quality of connections. Scheduled public transport services should run with fixed headway. The timetable headway determines the time between two scheduled services.

Despite the justified request that a public transport supply must be economically feasible, an adequate service quality for connections should be the aim. The service qualities should not fall below a minimum level of service required to meet a public service obligation.

The major criterion for the connection quality is running speed.

[3] The term “stop“, as used here, also covers railway stations and halts plus underground and light rail stations

Table 14: Categories for public transport and target running speeds

Category group		Category		Standard distance range [km]	Target running speeds [km/h]
HR	Mainline railway	HR 0	Continental mainline passenger rail services	200 – 500	160 – 250
		HR I	Long-distance mainline passenger rail services	60 – 300	120 – 160
CR	Regional railway outside built-up areas	CR I	Long-distance passenger rail services	40 – 200	50 – 110
		CR II	Interregional passenger rail services	10 – 70	40 – 100
		CR III	Regional passenger rail services	5 – 35	35 – 100
UR	Separate railway	UR II	Local passenger rail services, underground and light rail as a primary connection	–	30 – 45
		UR III	Local passenger rail services, underground and light rail as a secondary connection	–	25 – 35
LR	Light rail	LR II	Light rail and tram as a primary connection	–	20 – 30
		LR III	Light rail and tram as a secondary connection	–	15 – 25
		LR IV	Light rail and tram to provide access	–	10 – 20
UB	Tram/urban bus	UB II	Tram and bus as a primary connection	–	10 – 25
		UB III	Tram and bus as a secondary connection	–	5 – 20
		UB IV	Tram and bus to provide access	–	None
RB	Regional bus outside built-up areas	RB II	Interregional bus services	10 – 70	30 – 50
		RB III	Regional bus services	5 – 35	25 – 40
		RB IV	Local bus services	Up to 20	20 – 35

Table 14 contains targets values for public transport running speeds as a function of the category of a transport way. These running speeds also include the necessary waiting times at stops.

In the upper standard distance range, in particular, the higher running speeds should be taken as basis for the targets.

Regarding recommended standards on the time-related availability of public transport and the provision of public transport services, reference is made to publications (e.g. VDV, 2001, Bavarian Ministry, 1998, Hessian Ministry, 1998).

5.4 Network for cycling

In the interests of sustainable transport development, cycling is to be promoted by appropriately and systematically developing the network of cycling infrastructure. In particular, the potential for cycling on connections between urban and suburban areas, i.e. distances over 10 km, should be developed by providing appropriate cycling infrastructure. In the lower distance ranges, the modal share of cycling can be increased by improving the service quality for cyclists.

Transport ways for cycling uses transport infrastructure for motor vehicle traffic (on the carriageways or on a cycling facility alongside the road) and on the separate public or private road network (for instance separate cycle tracks, farm tracks, forest roads).

Everyday cycling and cycle tourism require a fundamentally different routing and design of cycling networks. Everyday cycling and cycle tourism connections between the same origins and destinations can thus run together on the same infrastructure or separately.

Transport ways for cycling are to ensure that the routes and junctions can be used safely. Another aspect of network development is the minimization of physical effort (detours, hills).

The most important criterion for the service quality of connections for everyday cycling is the minimization of time required. In the case of cycle tourism routes, it is the attractiveness of the routing. Transport ways for everyday cycling should therefore be routed as directly as possible (detour factor of maximum 1.2 compared with the shortest connection).

Transport ways for cycling should offer protection against violent assault. To this end, they are to be clearly laid out and easy to observe. When there is limited social policing, for instance at night, an alternative route through busy areas should be available, for which a higher detour factor can also be acceptable.

Table 15: Categories of transport ways for motor vehicle traffic and target running speeds for utility cycling

Category group		**Category**		**Standard distance range** [km]	**Target running speeds** [km/h[1)]]
OC	Outside built-up areas	OC II	Interregional cycling connection	10 – 70	20 – 30
		OC III	Regional cycling connection	5 – 35	20 – 30
		OC IV	Local cycling connection	Up to 15	20 – 30
IC	Within built-up areas	IC II	Cycling highway connection within a municipality	–	15 – 25
		IC III	Main cycling connection within a municipality	–	15 – 20
		IC IV	Cycling connection within a municipality	–	15 – 20
		IC V	Cycling access within a municipality	–	–

1) Including time lost at junctions

Cycling networks outside and within built-up areas should be well interlinked. This also applies to connections where the local/regional authority or the responsibility for road construction and maintenance changes. In addition, the cycling network is to be well interlinked with the public transport network and equipped with direction signage. This includes cycle parking at the access points and the associated range of services.

Outside built-up areas, the upgrading of cycling facilities on or alongside roads or of separately routed cycle tracks with paved surfaces regularly constitutes an encroachment on nature and the landscape. Existing paved farm tracks should therefore be included in the planning.

Because of their topographical conditions, transport ways for cycling on disused railway lines are very suitable. This also applies to river valleys and courses of brooks. In these places, however, there are frequently conflicts of objectives with water management and nature conservation interests.

Further information on the network development of transport ways for cycling can be found in the “Recommendations for Cycling Facilities” (ERA).

Table 15 contains targets for utility cycling speeds. These also include the necessary waiting times at junctions.

5.5 Network for pedestrian traffic

Pedestrian traffic occurs both as a sole means of transport and in combination with a trip by car or public transport. In the interests of sustainable transport development, it can be promoted by, among other things,

- short, accessible and direct footways to everyday destinations such as workplaces, training centres, kindergartens, shopping and leisure facilities and public transport stops,
- an appropriate network concentration in the catchment areas of everyday destinations, especially of public transport stops,
- traffic safety and personal security and
- attractive and sufficiently wide footways.

An attractive network of footpaths is also characterized by closely meshed, continuous footways, interruptions in walking that are as short as possible (for instance crossing aids, short waiting times at traffic signals) and minimum impairment by motor vehicle traffic (exhaust fumes, noise) or cyclists.

The network for pedestrian traffic is to be designed such that it is accessible (cf. Act on Equal Opportunities for Disabled Persons). The dimensions of footways are based on the nature and extent of their structural use. The width of footways is generally determined based on the criteria of freedom of movement and amenity and not on demand aspects. Information on the design of pedestrian traffic facilities can be found in the Guidelines on the Design and Construction of Urban Roads and the Recommendations for Pedestrian Traffic. Installations with high pedestrian activity (for instance in and around railway stations, event venues with a large number of visitors, at crossing points and on waiting areas), the sizing procedures can be found in the German Highway Capacity Manual.

Category group OP transport ways are separate footways or footways alongside roads. Shared footways/cycle tracks are the rule.

Category group IP transport ways are footways alongside roads with adjacent development and separate footways, for instance in green spaces. Because of the high level of mutual impairment, shared footways/cycle tracks should only be constructed in accordance with the fields of application of the Recommendations for Pedestrian Traffic Facilities. Provision for mixed-use areas can only made if there is a very low level of motor vehicle traffic.

5.6 Transfer nodes

5.6.1 General

Sustainable development of the transport systems calls for a dovetailed design of the transport networks. In this context, the integrated design of the transport networks should be promoted by their functional augmentation.

Meaningful functional augmentation should support the creation of intermodal journey chains through the advantageous interaction between several transport systems and/or means of transport. To this end, the transport networks should be augmented by a systematic scheme of transfer nodes.

The following information deals with transfer nodes within a transport system and with transfer nodes that between transport systems.

5.6.2 Importance of transfer nodes

Transfer nodes connect transport ways of one or several transport systems. The importance of transfer nodes can be derived from the category of the interlinked transport ways. At transfer nodes of major importance, it is usually the case that more than two categories of transport ways are interlinked.

The importance of a transfer nodes is the decisive factor influencing the requirements that it has to meet, although the specific conditions of a transfer node have to be taken into account on a case-by-case basis. From the importance in any given case, quality requirements to be met by the transfer node processes can be derived which, in turn, determine the functional design and equipment of a transfer node.

The location and design of the transfer nodes is to ensure that they are used in line with their functions. This applies to the transport and non-transport functions (table 16), which are normally mutually dependent. It is frequently the case that personal security and amenity for waiting passengers cannot be achieved until there is adequate non-transport use.

Table 16: Functional claims on land use and requirements to be met by transfer nodes

Function		Functional claims on land use and requirements
Traffic-related	Connection	– Transport service quality – Capacity
	Linkage/access	– Provision of linkages within and across transport systems – Convenience of the linkage – Ease of access for private motorized and non-motorized traffic – Ease of access for people with reduced mobility (accessibility) – Facilities for parking vehicles (P&R, B&R) – Information about connections – Provision of assistance for direction-finding and comprehensibility
Non-traffic-related	Amenity	– Opportunities for lingering, experience, communication – Safety, security and comfort (social policing, brightness, shelter, etc.)
	Integration into the urban context	– Structure, quality of the land uses – Integration into the urban environment – Architectural quality, design and identity – Potential for development in the surrounding area
	Nature and landscape	– Ecological aspects – Integration into the landscape
	Supplementary uses	– Retail, bank, services – Restaurants – Advertising – Event and conference venues – Other facilities (kiosk, toilets, telephone, etc.)

5.6.3 Location of transfer nodes

The location of transfer nodes on the transport network is to be taken into account in the functional categorisation of the transport networks. When assigning the connectivity function levels (section 3.3) from a direct line to the transport networks, the location of transfer nodes between transport systems should be planned. In the case of linkage between public transport (railway, tram, bus) and private transport (car, cycling, walking), they are normally predetermined by the location of the stations and stops. When creating new public transport stops, it is also advisable to re-investigate the systematic structure of transfer nodes.

The location of the transfer nodes shall achieve a high level of user acceptance. For this reason, transfer nodes for workday commuter traffic at locations near commuters' homes are advantageous.

Park & Ride sites (P & R)

The interlinking of private motorized transport and public transport is to be concentrated at stations and stops that provide high-capacity access links compatible with the surrounding environment and sufficient parking facilities. Suburban or peripheral locations are therefore often suitable. However, they can be problematic in terms of personal security.

P & R sites should be established with a certain concentration of services as near as possible to peoples' homes. By contrast, focusing on just a few large P & R sites widens the catchment area and results in a location that is more distant from peoples' homes. In the case of large P & R sites, the economic issues relating to the operation of the large site are of importance.

Use of the P& R sites should be supported by providing targeted traffic information and suitable route guidance.

Bike and Ride sites (B & R)

Linkage between cycling and public transport should be possible at a large number of stops and stations. Compared with Park & Ride, Bike & Ride should be designed as a wide-area strategy.

Large Bike and Ride sites are occasionally necessary if there is a great concentration of corresponding demand. They may be advisable on railway lines with a high level of regional commuter connectivity.

B & R sites are also recommended in central urban areas.

Further planning and design recommendations for Park & Ride/Bike & Ride can be found in the "Notes on P+R and B+R (FGSV, 2018) and the "Notes on cycle parking" (FGSV, 2012, Hessian Ministry, 2003).

Carpool parking areas

Carpool parking areas should be located directly at road network junctions. Motorway junctions, in particular, provide the possibility for carpooling, thereby reducing the car traffic volumes.

Transfer stops

Public transport transfer points should, wherever possible, offer a concentration of different transfer options with short transfer times. They are therefore to be located at central locations wherever possible.

5.6.4 Quality requirements and design principles

Irrespective of the type of interlinked transport systems, the following general quality requirements apply:

- short and convenient walking distances between the means of transport,
- if walking distances are unavoidably lengthy, shelters should be provided wherever possible,
- obstacle-free routes with the possibility of carrying luggage easily (if necessary, assistance with the carriage of luggage)
- protection against theft and vandalism by providing vehicle parking and left luggage facilities,
- promotion of personal security by means of visibility and sufficient lighting (to prevent intimidating spaces),
- unrestricted accessibility for mobility-impaired persons (for instance dropped kerbs, tactile elements).

Because of the different properties of the transport systems, there are, in addition to the fundamental requirements to be met by transfer nodes, also specific features that have to be taken into account in the design of transfer nodes.

The different links present at a transfer nodes are to be weighed against one another. The links with high demand flows should be given precedence.

Bike & Ride sites

Since protection against theft and vandalism is a major aspect of cycle parking at and around stations, the freely accessible parking facilities should also be augmented by cycle lockers or, at larger transfer nodes, cycle parking station. Additional services – such a cycle parking station with service – can make use more attractive. Parking facilities for Bike & Ride should satisfy specific criteria (see "Recommendations for Cycling Facilities").

The carriage of cycles on public transport is facilitated by cycle-friendly access (e.g. lifts where there are differences in height). Network planning should generally take account of good linkage between cycling and stops by providing suitable access routes.

Park & Ride sites

In addition to long-stay and short-stay parking spaces, it may be necessary to provide stopping areas for Kiss & Ride and possibly car rental pick-up and return facilities and car-sharing facilities.

Linkage between public transport

Linkages in public transport should be operationally optimized to achieve short waiting times when transferring (integrated regular interval timetables). It is also advisable to optimize organization and fares/ticketing in order to reduce the loss of time when changing means of transport. For long-distance transport, convenient options for the carriage of luggage (conveyor belts, service providers) are desirable.

6 Glossary

Category

The category of a transport way is the result of a combination of a category group and a connectivity function level.

Category group

The category group classifies the transport ways for motor vehicle transport, public transport, cycling and pedestrian transport according to the relevant type of transport, the location in relation to built-up areas and the environment surrounding the transport way.

It characterises the interaction between the carriageway and the environment surrounding the carriageway.

Connection

A connection is a directional relation of two places or traffic zones, also referred to as an origin-destination pair.

Connectivity function level

The connectivity function level describes the importance of a connection between an origin zone and a destination zone. It results from the importance of the connected zones which rise from the system of central places.

Connection-related service quality

The service quality of a connection measures the degree to which user-related requirements on connections are met. It is evaluated using several criteria, with time required being the core criterion.

For assessing the service quality of connections spatial routes in the road network and public transport connections derived from the timetable may be analysed.

Criterion

A criterion is used to describe the impact of a transport supply with regard to the expectations of the transport user (for instance the time required).

Direct-line connection

A direct-line connection is a straight line from an origin zone to a destination zone. A set of relevant direct-line connections is recorded in a direct-line matrix.

Indicator

The indicator quantifies the impacts of a criterion (for instance, time required is quantified by the "trip time" indicator or by the "direct speed" indicator that is derived from it).

Indicators are observed through measurements or calculated with the help of models.

In-vehicle time

In-vehicle time describes the time required to move in a vehicle between two points in the network.

In private transport, in-vehicle time also includes waiting times at intersections at the beginning and end of as well as within the network section caused by signal control or right-of-way rules. It depends on the maximum technical speed of the vehicle or the physical capabilities of a cyclist, on the route selected, on the speed limit and on the traffic volume of the network elements along the route.

In public transport, in-vehicle time also includes the dwell times of the vehicles at intermediate stops. It is pre-determined by the timetable.

Link

A link is a transport way between two nodes.

Level of service

A service level is used for a differentiated assessment of the degree to which an objective has been achieved.

The Guidelines for Integrated Network Design distinguish six different levels of service for assessing the service quality of connections.

Network element

A network element of the transport network is a link or a node.

Network section

A network section is a sequence of network elements along a transport way with the same connectivity function level and the same category group, i.e. the same category. If the category group changes at a point (for instance a road passing through a built-up area on the road network) or the connectivity function level changes at a junction, a new network section begins. A network section is limited by node at which the transport way in question is connected to a transport way with an identical or higher connectivity function level. It includes these nodes. A network section may contain further nodes at which the transport way in question is connected to transport ways with a lower connectivity function level (access node).

Node

A node is an intersection, a T intersection, a railway switch or a public transport stop.

A node in the road network is either a node at the beginning or end of a network section or an access node within a network section.

A public transport stop is either a node at the beginning or end of a route or a stop within a network section.

Public transport supply

The public transport supply comprises the physical infrastructure and the line services for transporting passengers.

Ride time

Public transport trip time comprises the trip time excluding access and egress time and excluding origin wait time at the first boarding stop.

Route

A route consists of several network sections and describes the spatial course of a movement from an origin zone to a destination zone. There may be more than one route between two traffic zones, which differ in terms of the service quality, traffic safety and impact on adjacent uses.

Routes relate to a single transport system (for instance in car transport) or a combination of transport systems (for instance in public transport by bus and rail).

Running speed

Running speed on a network section is a result of the quotient of the length of the network section and the in-vehicle time on the network section.

Scheduled public transport services

Scheduled public transport services comprise the public transport services and the timetable.

A public transport service runs on a predetermined route according to a timetable. The route of a public transport service starts and terminates at a node (stop) and usually traverses several nodes (intersections, switches) and further stops.

The timetable comprises a set of scheduled public transport vehicle trips describing the temporal characteristics of the public transport supply.

Standard distance range

The standard distance range refers to those distances that account for around 90 % of all connections of a connectivity function level. If the relevant distance of a connection under consideration is towards the upper end of the standard distance range, the higher values of the quality requirements should generally be aimed for, if the relevant distance is towards the lower end, the lower values will generally suffice.

Target value

The target value defines the value an indicator should achieve taking into account the possibilities and consequences.

The Guidelines for Integrated Network Design provide target values for the accessibility of a central place and for the running speed on a network section as a function of the category.

Track

Public transport vehicles uses tracks. The tracks for public transport comprises railways and roadways.

Transfer node

A transfer node is a point in the network at which travellers transfer between vehicles of one or several transport systems.

A distinction is made between:

- transfers within a transport system (public transport transfer stops) and
- transfers between transport systems (for instance Park & Ride sites, mainline stations, airports).

Transport connection

A transport connection comprises not only the spatial course of a movement (route) but also information on the temporal course of the movement (for instance on the departure and arrival times and times at transfer stops).

Between an origin zone and a destination zone, there is normally more than one transport connection, which may run along one or more routes.

Transport network

A transport network comprises the network elements nodes and links.

Transport system

A transport system comprises all components necessary for the operation of a means of transport which are of importance to a transport user:

- transport networks,
- vehicles that operate on the transport networks,
- public transport timetables and
- user charges (fares, road user charges and parking charges).

Transport way

A transport way is the generic term for the infrastructure in a transport network regardless of the type of transport system (roadway, railway, waterway, cycleway, walkway).

Travel demand

Travel demand describes the number of movements of travellers.

Travel demand is recorded demand matrices. Since the Guidelines for Integrated Network Design do not make any statements on the capacity or capacity utilization of network elements, demand matrices are not used.

The assessment of the service quality of connections is based on direct-line connections (consolidated in direct-line matrices). The direct-line connections describe the relative importance of a connection without explicitly considering travel demand.

Trip speed

Public transport trip speed results of the quotient of the length of the network section and the trip time required on the network section.

Trip time

Trip time describes the time required to move from an origin to a destination

In private transport, trip time includes not only in-vehicle time but also access and egress times and time spent searching for a parking space.

In public transport, trip time includes not only in-vehicle time but also access and egress times and waiting time at boarding and transfer stops.

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Annex

A 1 Guidance for performing the functional categorisation

A 1.1 Identification of the direct-line networks

A good way to identify the direct-line networks of a connectivity function level is to establish, as a first step, so-called triangular networks. This involves linking the central places of one centrality level to neighbouring places of the same centrality level in such a way that the lines do not overlap.

On these triangular networks, the nearest and nearest-but-one neighbours can be determined for any central place O (figure 8). Studies on real-life networks have shown that, for direct-line networks of connectivity function category 0, all metropolitan regions (MRs) should be linked with one another. The result is that for each connectivity function level, a direct-line matrix is produced that is symmetrical, i.e. there is a direct-line connection for each direction (centre i to centre j and centre j to centre i).

The direct-line from one central place to the nearest place of higher centrality is as a rule automatically part of the concerned direct-line networks. If this is not the case, it will suffice to check, after allocating the direct-line networks to the transport network, whether each central place is suitably connected to the transport network of the next higher connectivity function level.

A 1.2 Allocation of the direct-line networks to the transport network

The direct-line networks are allocated separately for each connectivity function level, starting with the highest connectivity function level. In the case of a computerized method, the following specifications must be taken into account when searching for routes.

- In private motorized transport, the search for routes should be based on an uncongested network. In city-regions, however, it may be appropriate to include additional time lost at junctions, for instance by means of turning supplements.
- In public transport, the route searching method depends on the planning task. In the case of the long-term planning of new railway infrastructure, a simple route search on the basis of the travel time of each railway link may suffice. For the planning and appraisal of line networks, frequency-based or timetable-based search methods are required (Friedrich et al., 2001).

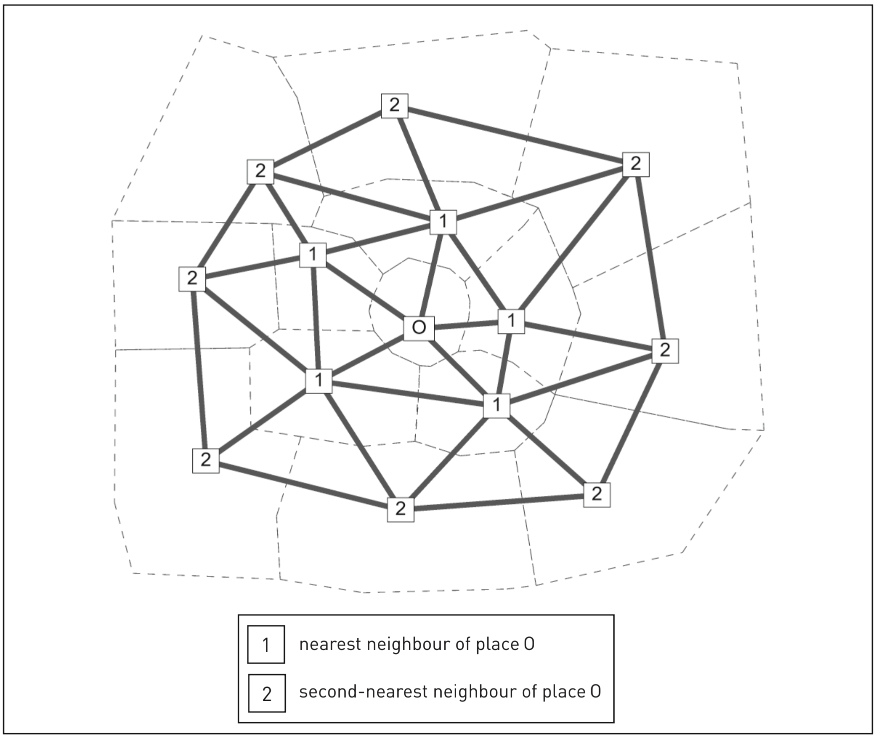


Fig. 8: Triangular network for identification of the direct-line networks

By varying the assignment parameters, alternative routes can be generated and analysed in the planning process. If, in car transport, for instance, an impedance function of the following form is chosen

$$w = \alpha \cdot t + \beta \cdot l$$

where
w = impedance in seconds
t = time in seconds
l = length in metres
α = time parameter [–]
β = length parameter [s/m]

parameters α and β can be used to influence the result of the route search. For $\alpha = 1$ and $\beta = 0$, the route with the shortest time is identified. For $\alpha = 1$ und $\beta > 0$, a route that is shorter in length, i.e. a more direct route, may result. The decisions as to which of the routes is ultimately chosen is up to the planners. Varying parameters α and β makes it possible to generate and analyse alternative routes in the planning process. An adapted impedance function can take into account special requirements when determining routes.

- **Bundling to fast roads:** if the aim is to concentrate traffic flows on fast roads, the following parameter values are recommended: $\alpha = 1$ and $\beta = 0$.
- **Bundling to safe roads:** if traffic flows are to be concentrated on safe dual carriageways in order to counter the heightened risks on single carriageways, road specific parameter can be chosen for these network stretches: $\alpha < 1$ (e.g. $\alpha = 0.8$).
- **Low detours:** if detours are to be avoided, the following parameter value should be chosen: $\beta > 0$ (e.g. = $\beta = 0.01$ to 0.02). This case will lead to larger network lengths for a connectivity function level, because the connections are concentrated on fast roads to a smaller extent.

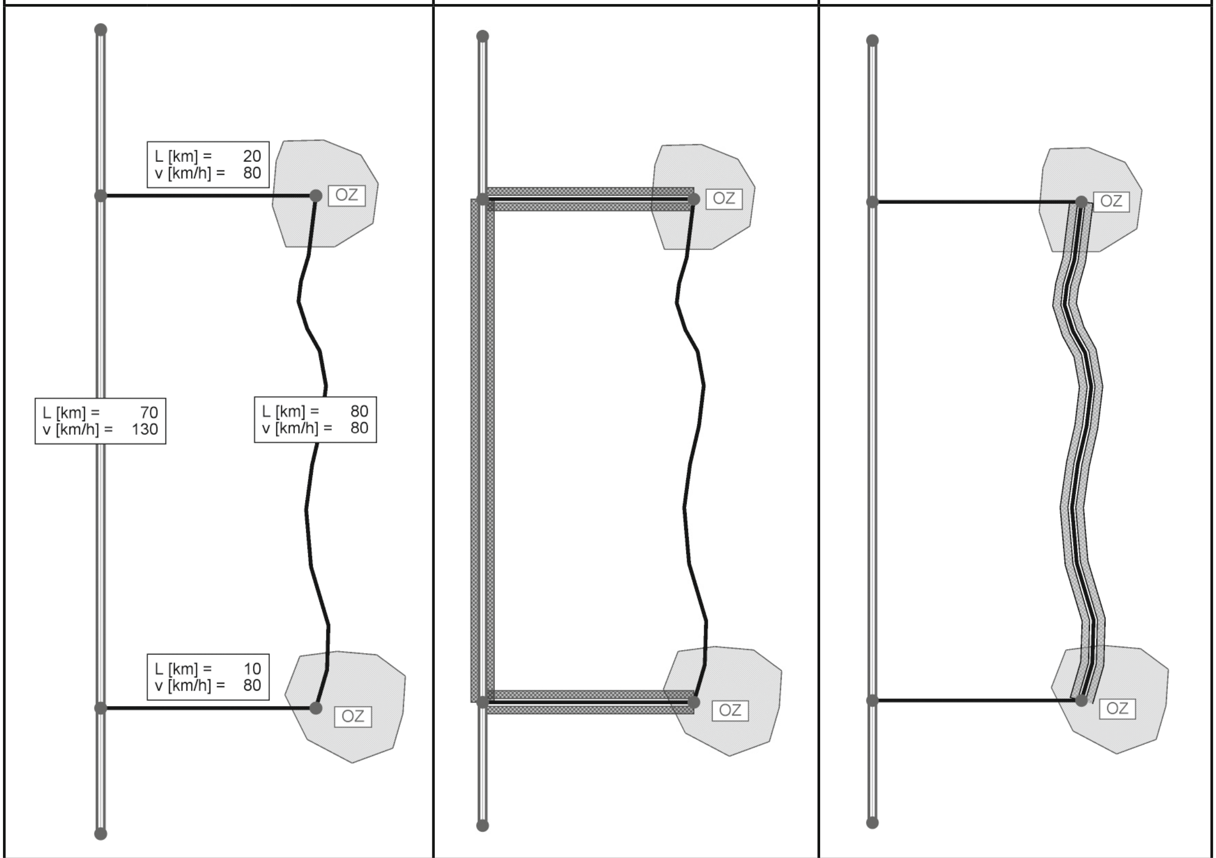
Table 17: Categories and value levels of ecosystems

Level	Level of importance	Species- or population-related criteria	Area-related criteria	Formal criteria
I	International	Final occurrence of species threatened by global extinction, relict areas; occurrence of species of global or pan-European importance	Areas that are unique globally or on a pan-European scale, such as tidal flats, shallow coastal waters, riverine fens, large semi-natural beech forests	Ramsar sites and sites of Community importance, European special protection areas, biosphere reserves, global research priorities (MAB)
II	National	Occurrence of species or biological populations that are threatened by extinction or endangered and have a low level of incidence in Germany, incidence of species of national (Central European) importance	Especially valuable, large-area, natural ecosystem complexes	National and nature parks, special biotopes as described in Section 30 of the Federal Nature Conservation Act, nature reserves in the financial assistance programme entitled "establishing and safeguarding nationally representative natural and landscape areas in need of protection"
III	State-wide/regional (federal state, region)	Occurrence of species that are threatened by extinction or endangered, and have a low level of incidence in Germany, incidence of species of state-wide (Central European) importance	Natural and semi-natural ecosystem types	Nature reserves, landscape protection areas, other biotopes as described in Section 30 of the Federal Nature Conservation Act, area-related functional designations of the landscape programmes and framework plans
IV	Local(district, municipality)	Occurrence of endangered species of local (district-specific) importance		Protected parts of the landscape, natural monuments and area-related functional designations of the landscape plans

– **Bypassing ecologically sensitive areas:** to mitigate existing encapsulation of natural habitats or prevent new fragmentation, the impedance on transport ways can be increased by means of ecologically sensitive areas (table 17). This can be achieved by applying a specfic β parameter. Transport ways in ecologically sensitive areas are allocated a higher parameter value for β (e.g. β = 0.03 to 0.04).

Figure 9 illustrates the influence of the chosen impedance function on the route search and thus on the categorization of road networks. In the example illustrated, there exist two routes for linking the higher-order centres. Route 1 goes via the motorway and exhibits a length of 100 kilometres and a travel time of 55 minutes (3,300 seconds). Route 2 goes via a rural road and exhibits a length of 80 kilometres and a travel time of 60 minutes (3,600 seconds). Depending on how parameters α and β are weighted, the result is either route 1 or route 2.

Network	Route 1 results with $w = 1{,}0 \cdot t + 0{,}0 \cdot l$	Route 2 results with $w = 1{,}0 \cdot t + 0{,}02 \cdot l$



	Time [s]	Length [m]	Impedance	Impedance
Route 1	3,300	100,000	3,300	3,300 + 2,000 = 5,300
Route 2	3,600	80,000	3,600	3,600 + 1,600 = 5,200

Fig. 9: Influence of the impedance function on the route search

After the direct-line networks have been allocated to the transport network, the number of connections of a connectivity function level that pass through every network element is known. The relevant connectivity function level is determined by the highest connectivity function level. In this way, it is possible to determine the connectivity function level not only for links but also for junctions.

A 1.3 Correcting the connectivity function level in the vicinity of central places

Unlike rail networks, high-level road networks are not to be routed right into the centre of a central place. Instead, only roads required for connections within central places should be classified as high-level road.

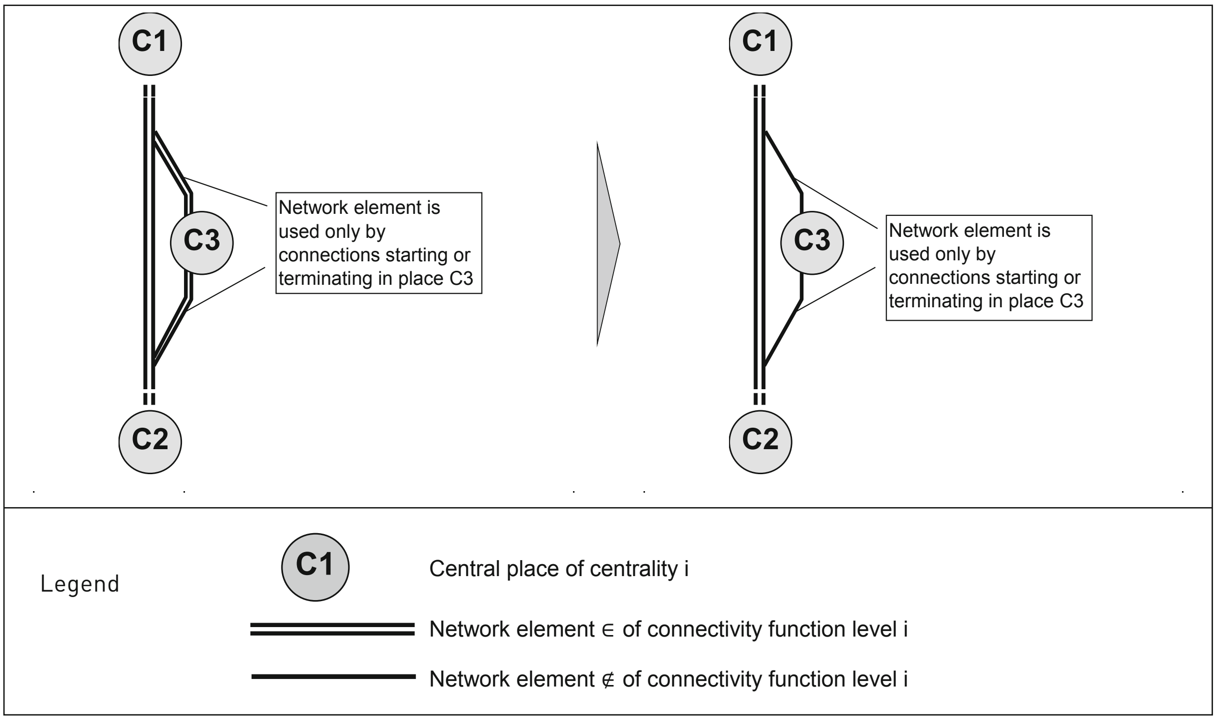


Fig. 10: Correction of the connectivity function level by removing networks elements that are only used by connections that start or terminate in a place (in this case C3))

This involves considering the road network with which the central place is connected at one or more nodes of the higher-level road network.

First, in the vicinity of a central place, those network elements are eliminated from the network of connectivity function level i that are used exclusively for connections that start or terminate in this place (Fig. 10).

To identify this part of the network in a transport model, three sub-steps are required, as shown in figure 11 for a place O:

1. Allocation of all direct-line connections of connectivity function level i to the road network. Superimposing all connections produces a number BTOT of these connections for each network element.
2. Allocation to the road network only of direct-line connections of connectivity function i that start or terminate in place O. Superimposing these connections produces a number BO of these connections for each network element.
3. Creation of the difference BDIFF = BTOT – BO for all network elements. Network elements for which BDIFF assumes a value of 0 are eliminated from the road network of connectivity function level i.

This correction can lead to a situation, where a longer sequence of network elements in the vicinity of a central place would have to be eliminated. Special cases of such situations are shown in figure 12:

– In the first two cases, the network elements between central places C1 and C2 would be eliminated, because they are used only by the connection C1 - C2.
– In the third case, the network elements between central place C1 and node N1 would be eliminated, because they are used only by connections starting or terminating in C1.

However, eliminating such a sequence of network elements would not be appropriate. It should therefore not be done if the total length of the network elements to be eliminated exceeds the maximum lengths shown in table 18 (see also figure 13).

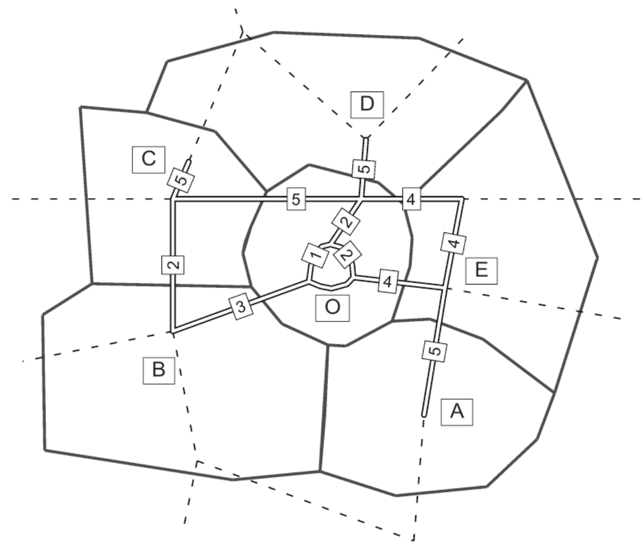
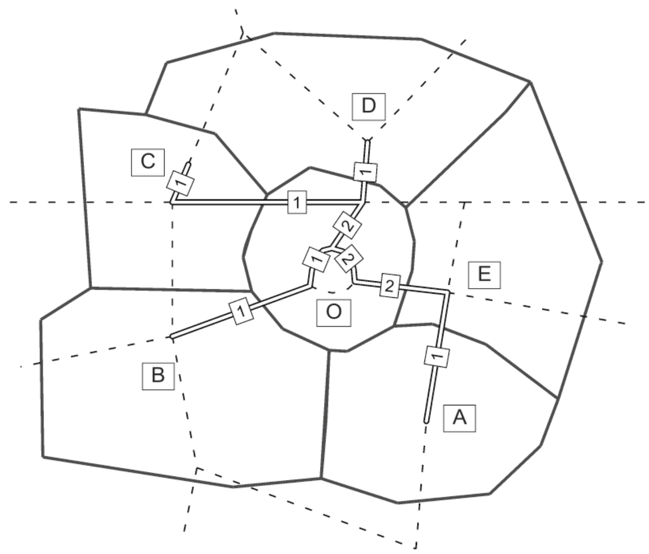
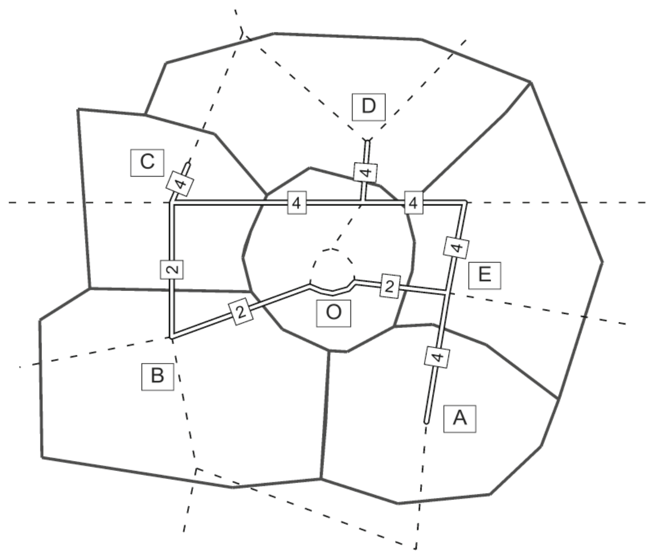
1. Allocation of all direct-line connections to the road network → B_{TOT}	
2. Allocation of direct-line connections to the road network that start or terminate in place O → B_0	
3. Difference of $B_{TOT} - B_0$ gives the network of a specific connectivity function level	

Fig. 11: Correcting the connectivity function level in the vicinity of central places

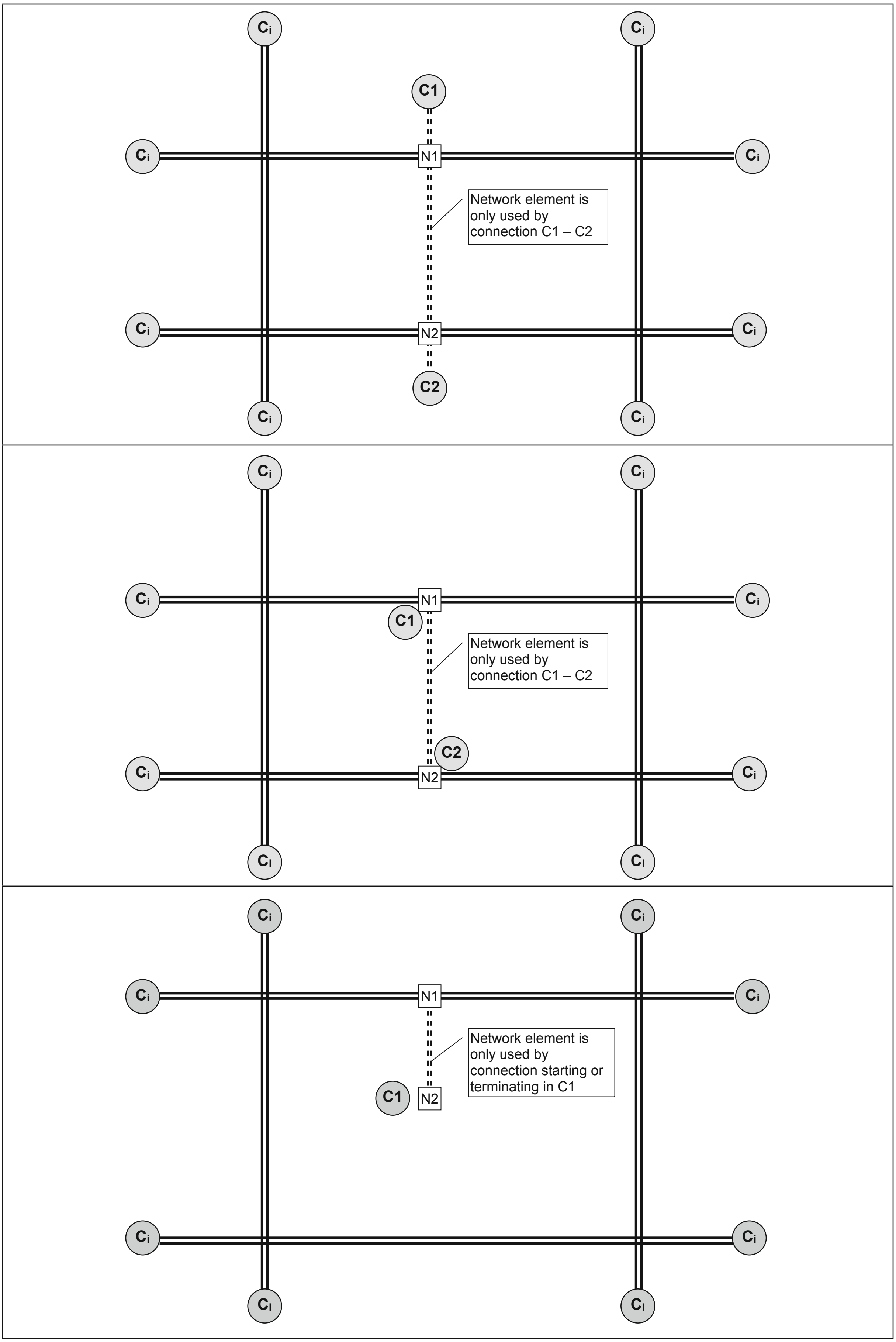


Fig. 12: Special cases in the correction of connectivity function levels in the vicinity of central places

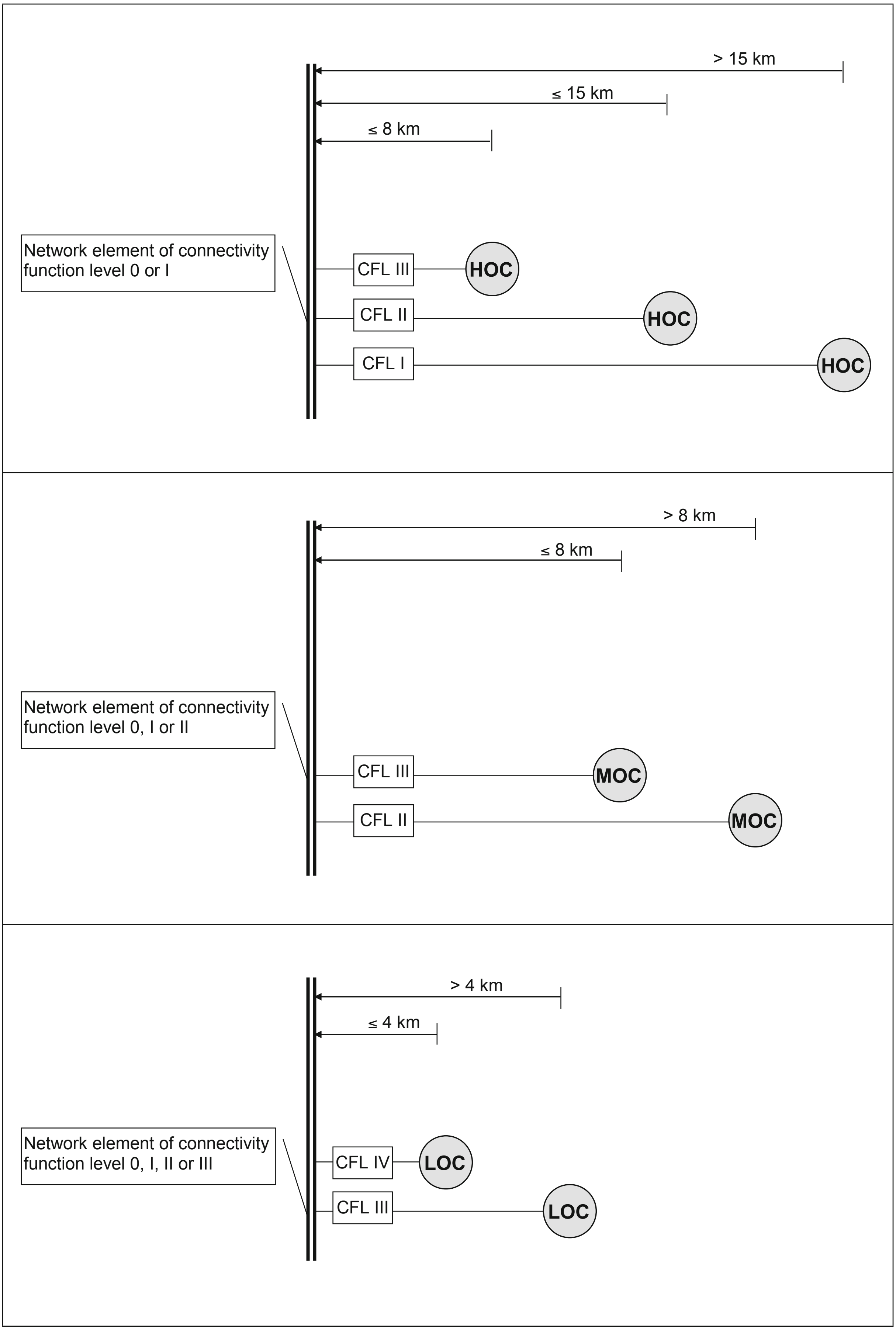


Fig. 13: Categorisation of network elements for connecting central places depending on the distance from the higher-level network

Table 18: Reference values for the maximum length of a sequence of network elements to be eliminated

Connectivity function level	Maximum length l_{max}
0	30 km
I	15 km
II	8 km
III	4 km

The road network resulting from these model-based correction steps should be visually checked for small gaps between open network ends of a certain connectivity function. If necessary, the network has to be completed manually.

Figure 14 shows an example for defining the connectivity function level in the vicinity of a higher-order centre without through traffic from and to neighbouring higher-order centres.

- The second-nearest connection from MOC1 to MOC2 passes through the higher-order centre. Since there is a bypass around the higher-order centre, this connection is allocated to the bypass with connectivity function level II. Thus, all nodes along this connection are likewise allocated to connectivity function level II.
- The second-nearest connection from MOC1 to MOC3 also passes through the higher-order centre and is allocated to the bypass. However, this does not result in any new nodes of connectivity function level II.
- The two transport ways from the higher-level road network of connectivity function level 0/1 to the higher-order centre are allocated to connectivity function level I, because the distance exceeds the maximum length of 15 km.

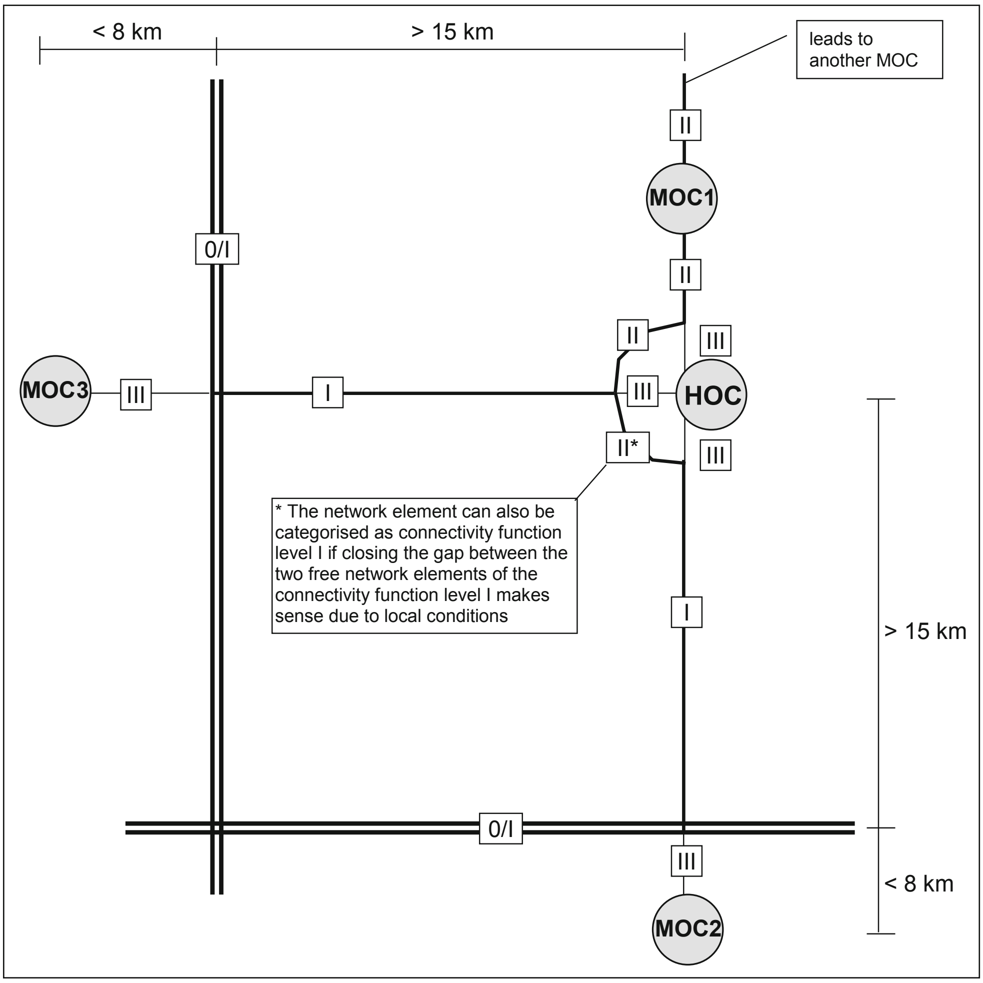


Fig. 14: Example of the categorisation of network elements in the vicinity of a higher-order centre through traffic from and to neighbouring higher-order centres

- Connectivity function level I ends at the point on the bypass where the two transport ways meet nodes of connectivity function level II.
- The southwestern part of the bypass is typically allocated to connectivity function level II. It can, however, also be classified as connectivity function level I, because these network elements connect two free ends of the network of connectivity function level I.
- All the other roads in the example are allocated to connectivity function level III.

A 1.4 Connecting transfer nodes

At the end of the functional categorisation, it is checked for each central place of centrality i whether it is adequately connected to the higher-level transport network of connectivity function level i-1. The same is done for transfer nodes (airports, ports, stations, freight villages). Depending on the importance of the transfer node, the aim is to ensure that the transfer node is well connected to the transport network of connectivity function levels 0 to II (see figure 5 and table 19).

Table 19: Connection of transfer nodes

Transfer node	Connection to the transport network of level
International airport International port	0
National airport National port National freight village Mainline station on the urban fringe	I
Regional freight village Mainline station in the city centre	II

A 2 Guidance on determining and evaluating the service quality

A 2.1 General approach

A decision which indicator values define a certain quality level is ultimately a transport policy decision of the responsible policymaker. This decision results in specific target values in individual cases. To provide guidance for an evaluation, a method for deriving service levels for evaluating the service quality of connections is described for an existing network. The provided benchmark values can serve as a starting point for evaluating existing networks. Ultimately, the responsible policymaker must determine which level of service quality should be considered acceptable and thus serve as the target for network planning.

The quality of services is determined and evaluated on the level of direct-line connections. This involves identifying routes for all direct-line connections defined in the direct-line matrix. For each route, indicators can then be determined which describe the service quality. This Guideline for Integrated Network Design considers the following indicators:

– times: trip time (including access and egress times);
– speeds: direct speed;
– lengths: trip length;
– directness: number of transfers, detour factor.

This results in the following sequence of steps for calculating the indicators:

4. Processing a particular direct-line connection, i.e. an origin-destination pair;
5. Performing a route search for each relevant transport system and each relevant combination of transport systems;
6. Identifying the indicator values for each route;
7. Assessing the indicator values based on quality levels.

The evaluation of a transport network requires the examination of a large number of origin-destination pairs. For this reason, a computer-aided method based on route search procedures is recommendable for determining indicator values. Transport planning programmes with an integrated traffic assignment are especially suitable for this calculation, but route planning systems or passenger information systems can also be used.

The evaluation functions for the assessment of direct speeds, trip time ratios, detour factors and number of transfers shown in the following sections are the result of an analysis which examined these indicators for a large number of selected connections in the existing transport network. The evaluation functions should be examined and developed further in future applications.

A 2.2 Level of service for direct speeds

The LOS curves shown here are suitable for assessing the traffic situation in car transport and public transport. Because of the system-specific characteristics of car transport (direct door-to-door trips with no transfers) and of public transport (access, egress, possibly transfers), the LOS curves assess the direct speeds differently for the modes. They are thus suitable for a sectoral assessment of the direct speeds of car transport (figure 15) and public transport (figure 16).

Figure 17 is suitable for an integrated comparison of the direct speeds of cars and public transport where the services quality of both modes need to be compared.

These LOS curves can also be used to assess combinations of transport systems (e.g. Park & Ride).

Since the distance corresponds to the connectivity function levels, the evaluation functions apply to all connectivity function levels. The evaluation functions for direct speed can be used only for a distance range starting from 5 km direct distance. Annex 2.6 provides background information on the evaluation functions.

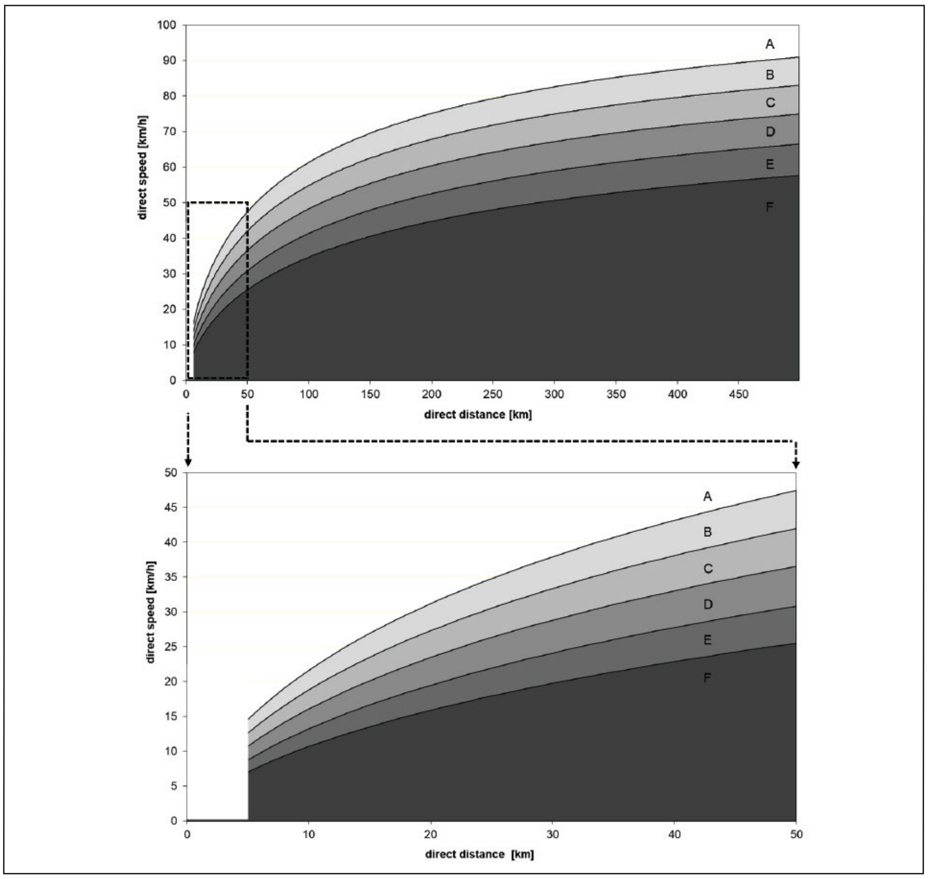


Fig. 15: Level of service for direct speed in car transport

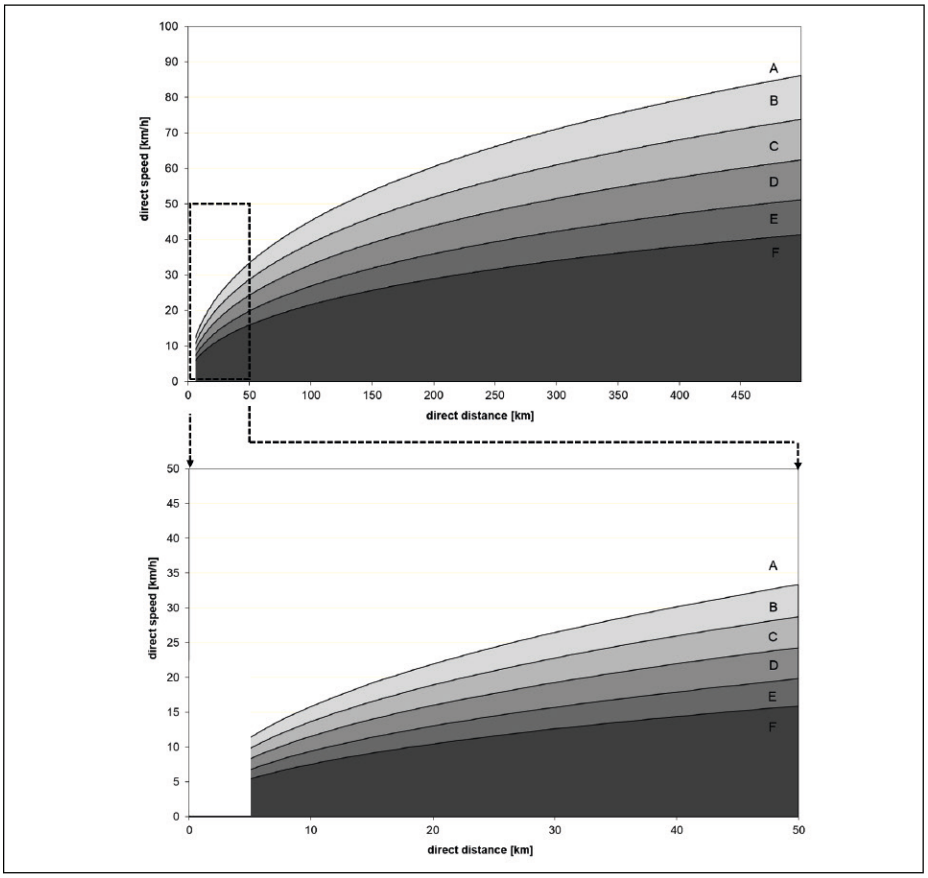


Fig. 16: Level of service for direct speed in public transport

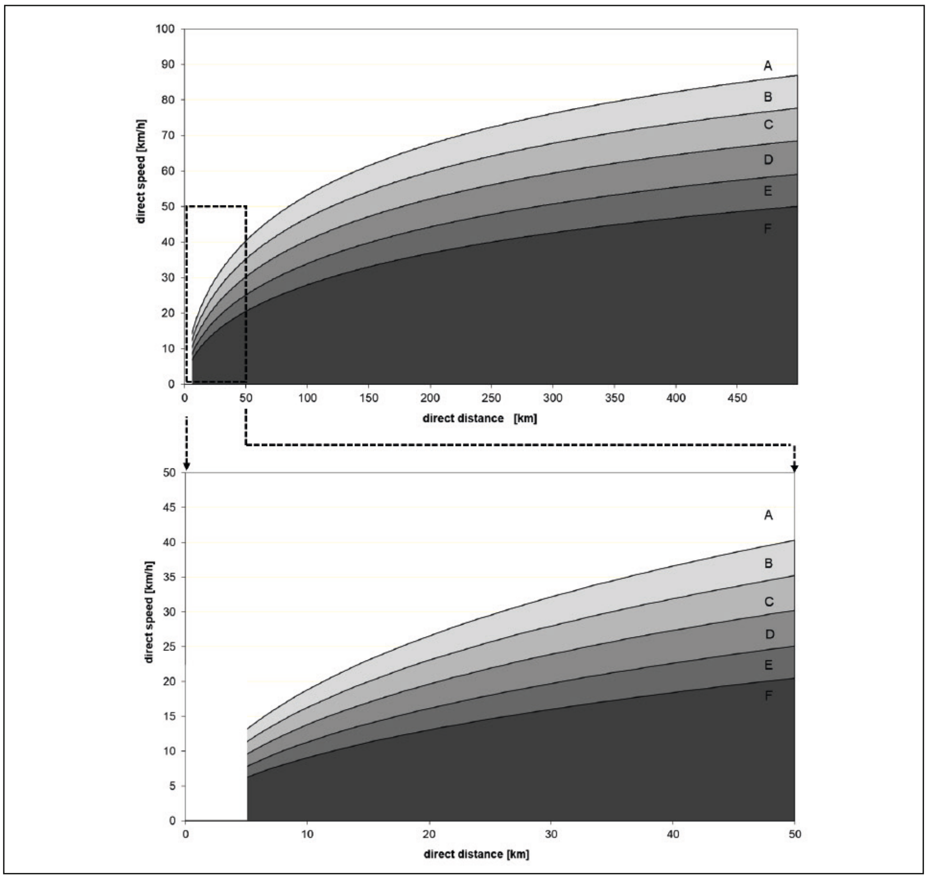


Fig. 17: Level of service for direct speed for a comparative assessment of car transport and public transport

A 2.3 Level of service for trip time ratios

Figure 18 contains benchmark values for the assessment of the trip time ratio of public transport to car transport. Annex 2.6 provides background information on the evaluation functions.

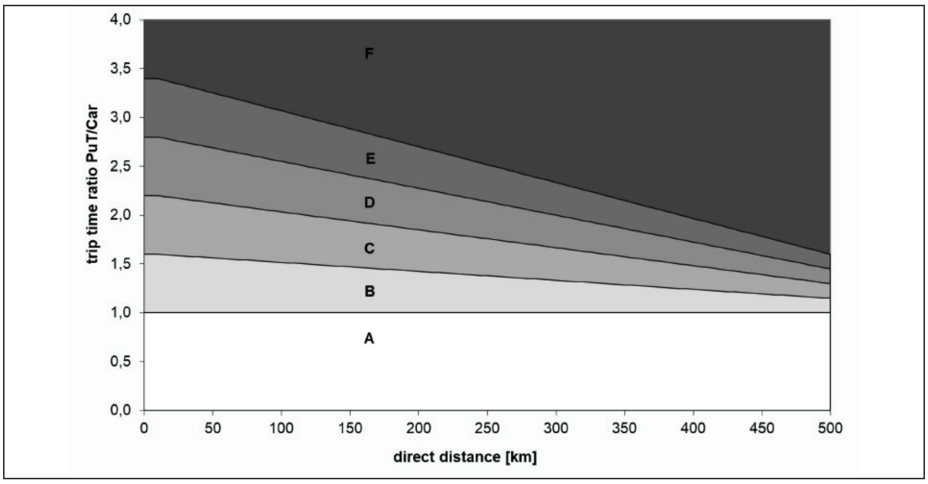


Fig. 18: Benchmark values for the assessment of the trip time ratio public transport to car transport

A 2.4 Level of service for detour factors

Figure 19 contains benchmark values for the assessment of detour factors. Annex 2.6 provides background information on the evaluation functions.

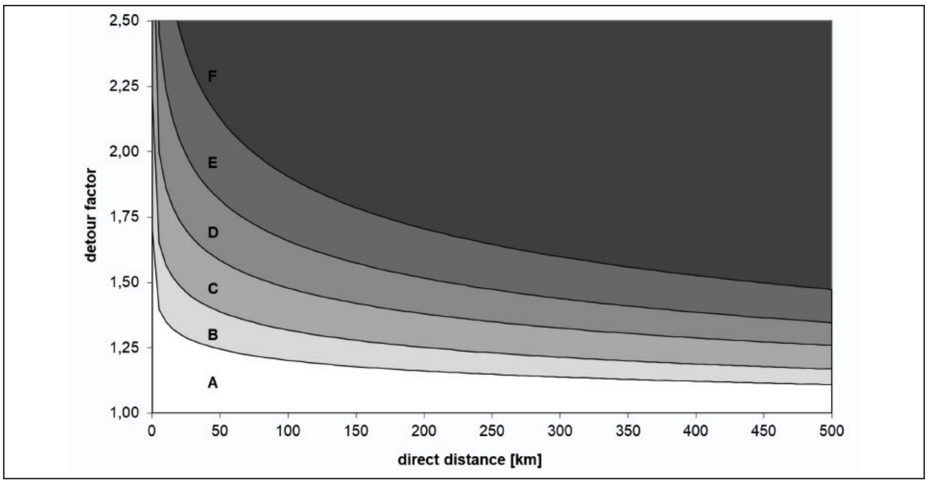


Fig. 19: Benchmark values for the assessment of detour factors

A 2.5 Level of service for numbers of transfers

Figure 20 contains benchmark values for the assessment of the number of transfers. Annex 2.6 provides background information on the evaluation functions.

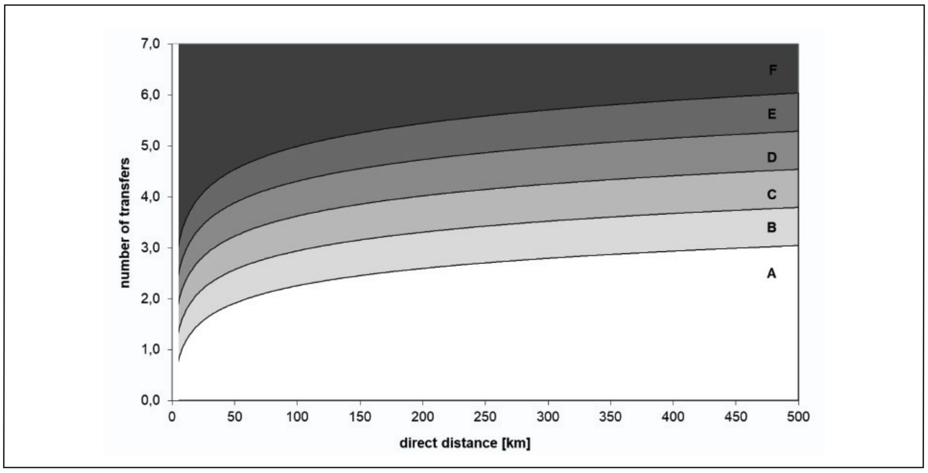


Fig. 20: Benchmark values for the assessment of the number of transfers

A 2.6 Guidance on determining indicators and service levels

A 2.6.1 Determination and aggregation of indicators

The direct speed results from the quotient of the direct distance and the trip time (figure 21).

$$v_{DV} = \frac{l_{DD} \cdot 60}{t_{TT}} = \frac{l_{DD} \cdot 60}{t_{AT} + t_{RT} + t_{ET} + t_{OWT}}$$

where
v_{DV} direct speed [km/h]
l_{DD} direct distance [km] between origin and destination
t_{TT} trip time [min]
t_{AT} access time [min]
t_{OWT} origin wait time at origin stop [min]
t_{RT} ride time [min]
t_{ET} egress time [min]

Fig. 21: Identification of the direct speed

The trip time in car transport depends to a large extend on the traffic situation during the time period of the trip. This time period may lie in off-peak or peak periods. In the case of long-distance trips, it can cover both time periods. In principle, three different approaches can be considered for determining the trip time:

Measuring the trip time

The trip time is determined by measuring times while travelling on the relevant routes. This approach delivers realistic values when the measurements are repeated over a longer period of time. This ensures that the result is not affected by random disruption. However, an approach of this kind is, for reasons of cost, not suitable for the analysis of a large number of connections. Nor can the method be used for planned networks.

Observing the trip time

The trip time is derived from the evaluation of observed movements from one point to another. Floating car data (FCD), floating phone data or data from number plate recognition systems are suitable for this. Traffic state data can be used for road network areas that are completely monitored by a traffic control centre. Again, measured values must be evaluated for longer periods of time.

Modelling the trip time

The trip time is determined using a macro- or microscopic transport model. This approach is also suitable for the analysis of large networks and planned networks. The prerequisite is a transport model validated with regard to trip time and based on reliable network and demand data for peak periods.

For public transport, the indicator values for trip time, trip length and number of transfers can be determined from the timetable with the help of timetable information systems or transport planning programmes with a timetable-based assignment timetable.

Especially in public transport travellers can often choose between alternative travel options differing in terms of ride time or number of transfers. In this case mean indicator values, as shown in table 20, must be calculated. For this purpose, a method is recommended that identifies relevant scheduled services and uses only these to determine the mean value.

Procedure

Calculate a perceived ride time (t_{PRT}) for each alternative travel option comprising the ride time (t_{RT}) and the number of transfers (NT):

- urban transport: t_{PRT} [min] = t_{RT} + NT · 3 min
- regional and long-distance transport: t_{PRT} [min] = t_{RT} + NT · 10 min

Calculate the maximum perceived ride time ($t_{PRT,Max}$). It is a result of the travel option with the minimum perceived ride time ($t_{PRT,Min}$):

- urban transport: $t_{PRT,Max}$ [min] = $t_{PRT,Min} \cdot 1.1$ + 5 min
- regional and long-distance transport: $t_{PRT,Max}$ [min] = $t_{PRT,Min} \cdot 1.1$ + 10 min

Table 20: Example of calculating mean indicators in public transport

No.	Departure	Arrival	t_{TT}		NT	t_{PRT}	Relevant
1	05.13	08.49	3.36	216 min	0	216 min	☑
2	07.06	10.21	3.15	195 min	1	205 min	☑
3	08.05	12.16	4.11	251 min	1	261 min	☐
4	09.08	12.21	3.13	193 min	1	203 min	☑
5	09.22	13.10	3.48	228 min	1	238 min	☐
6	10.05	13.20	3.15	195 min	1	205 min	☑
Minimum perceived ride time	$t_{PRT,Min}$ = 203 min						
Maximum perceived ride time	$t_{PRT,Max}$ = 203 min × 1.1 + 10 min = 233						
Number of relevant travel options	t_{RT} = < 233 min: N_{Option} = 4						
Mean ride time:	$t_{RT,Mean}$ = (216 + 195 + 193 + 195) / 4 = 199 min						
Mean number of transfers:	NT_{Mean} = (0 + 1 + 1 + 1) / 4 = 0.75						

Table 21: Access time, egress time and time spent searching for a parking space in car transport

Characteristics of the area	t_{AT}/t_{ET} [min]	t_{PST} when parking pressure is normal [min]	t_{PST} when parking pressure is high [min]
Core zone of a higher-order centre – Primarily used for shopping and personal business – Hardly any residential use	2.5	2.0	4.0
Core zone of a middle-order centre – Mixed use development – shopping, personal business, work – Little residential use	2.0	1.0	3.0
Core zone of a lower-order centre – Mixed use development – shopping, personal business, work – Medium residential use	1.0	1.0	2.0
City centre fringe of higher-order centre – Mixed use development – housing, work, shopping, personal business – Extensive on-street parking of residents' vehicles	2.0	2.0	4.0
Other areas – Primarily used for housing – Residents' vehicles are parked mainly on private parking spaces and there is little on-street parking	1.0	0.0	–

As relevant travel options, choose options where the perceived ride time is lower than the maximum perceived ride time. The travel option is relevant if perceived ride time < max. perceived ride time.

Calculate the mean ride time ($t_{RT,Mean}$) and the mean number of transfers (NT_{mean}) as the mean value of the relevant travel options (N_{Option}).

$$t_{RT,Mean} = \frac{\sum_{i=1}^{N_{Options}} t_{RT,i}}{N_{Options}} \qquad NT_{Mean} = \frac{\sum_{i=1}^{N_{Options}} NT_i}{N_{Options}}$$

A 2.6.2 Determination of connector times

An assessment of the service quality considers the indicators of an entire movement from the origin address to the destination address, i.e. from door to door. Thus, to assess the time required, the time a traveller spends walking from their door to the point at which they board the vehicle (access time) and the time they spend walking from the point at which they alight from the vehicle (egress time) must be estimated. In addition, the origin wait time in public transport and the parking search time in car transport must be taken into account. If the indicators are identified using digital network models that do not comprise the entire transport network, it is also necessary to estimate the travel time spent on the missing transport network. Cases of this nature occur in the case of network models which, for instance, only include rail services, so that the travel time spent on feeder services cannot be determined. In motor vehicle traffic, they occur in the case of network models which, for instance, only comprise the main road network and not the feeder network. When using route planning systems for car transport or public transport passenger information systems, this case does not normally occur, because they usually cover the entire transport network.

Another problem is determining representative values for the time components that correspond to the mean time required for a movement between two central places.

Access time, egress time and time spent searching for a parking space in car transport

The access time t_{AT}, egress time t_{ET} and time spent searching for a parking space t_{PST} depend primarily on the location and physical structure of the area. Access and egress times in car transport rise with increasing building density, because in densely built areas it is often not possible to park a vehicle directly at the starting or destination point of a trip. This leads to longer walking distances. In areas with a high level of parking pressure, where the demand for parking space regularly exceeds the supply of parking spaces, the time spent searching for a parking space is longer.

Travel time in the subordinate network in car transport

Travel time in the subordinate network t_{SN} depends mainly on the size of the traffic zones and the number of connected nodes. In addition, it must also be taken into account whether the transport network used for the route search contains all road links or not.

- Number of connected nodes = 1:
  If the trip time is identified using a complete road network, the travel time on the subordinate network is already included in the trip time if the centroid of the zone is used as the point of origin and destination. The centroid of the zone can be approximately determined from the coordinates of all network nodes in the area under consideration (mean value of the X and Y coordinates). The travel time in the subordinate network t_{SN} can then be set to 0.0 minutes. If the network model contains only the classified road network, the travel time on the subordinate network t_{SN} can be assumed to be 1.0 minute.
- Number of connected nodes > 1:
  In this case, the value for the travel time on the subordinate network t_{SN} can be taken from figure 22 as a function of the length of the connector l, i.e. the length of the link between the centroid and the network node. Here, the location of the zone, (higher-order centre, middle-order centre, lower-order centre or no centrality) is included in order to take account of the different travel speeds in urban and rural areas. In the case of large traffic zones (> 5 km^2), the values for lower-order centres should be used. If the network model contains only the classified road network, the travel time on the subordinate network t_{SN} is increased by 1.0 minute.

Access time, egress time and origin wait time at the first public transport

The mean access time t_{AT} and egress time t_{ET} to the nearest stop are typically between 3.5 and 5.5 minutes, irrespective of the area under consideration.

There is a less pronounced relationship between the access/egress time and the density of stops d in an area, as shown in figure 23.

The time spent waiting at the stop first stop of a trip, the origin wait time t_{OWT}, depends on the headway of the public transport vehicles. Figure 24 shows observed times spent waiting at the stop of origin as a function of the headway.

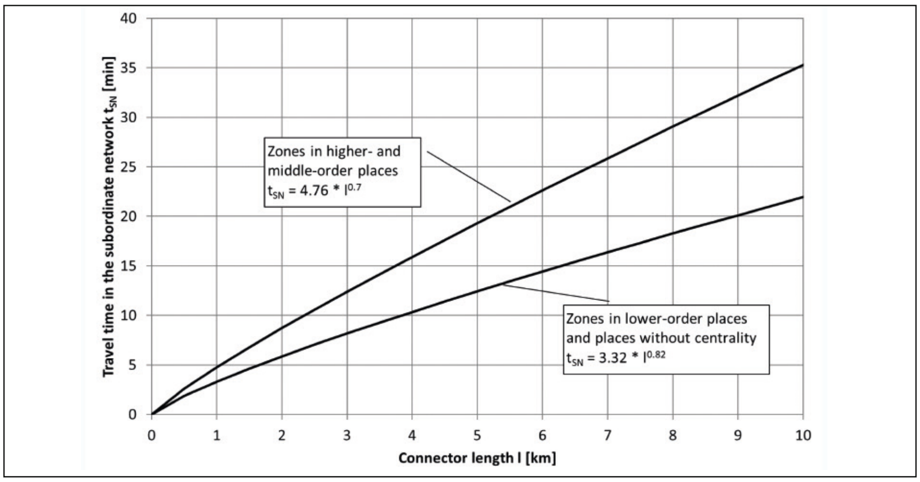


Fig. 22: Travel time t_{SN} on the subordinate network in car transport as a function of the connector length l

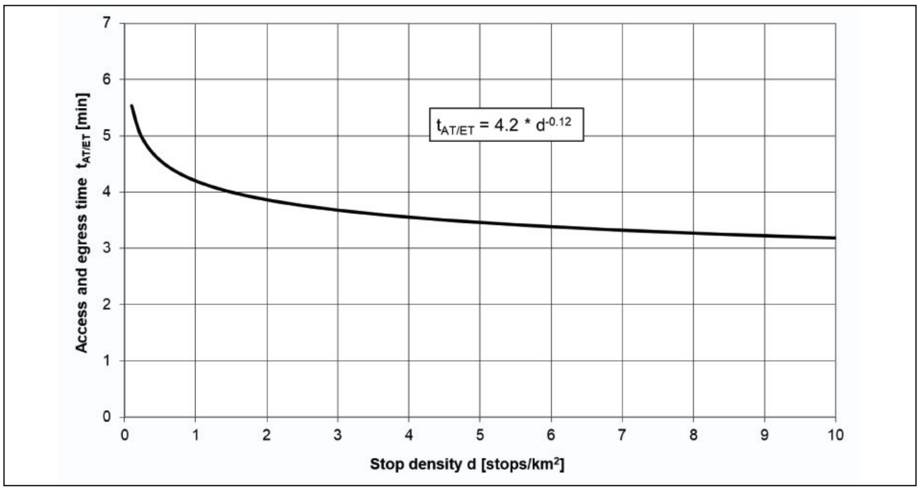


Fig. 23: Access time t_{AT} or egress time t_{ET} in public transport as a function of the density of stops d

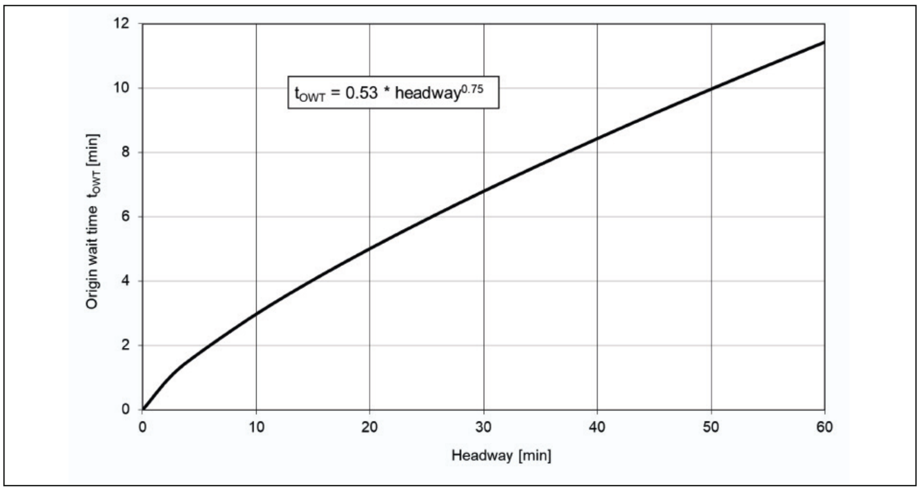


Fig. 24: Origin wait time t_{OWT} at the first public transport stop of a trip as a function of the headway

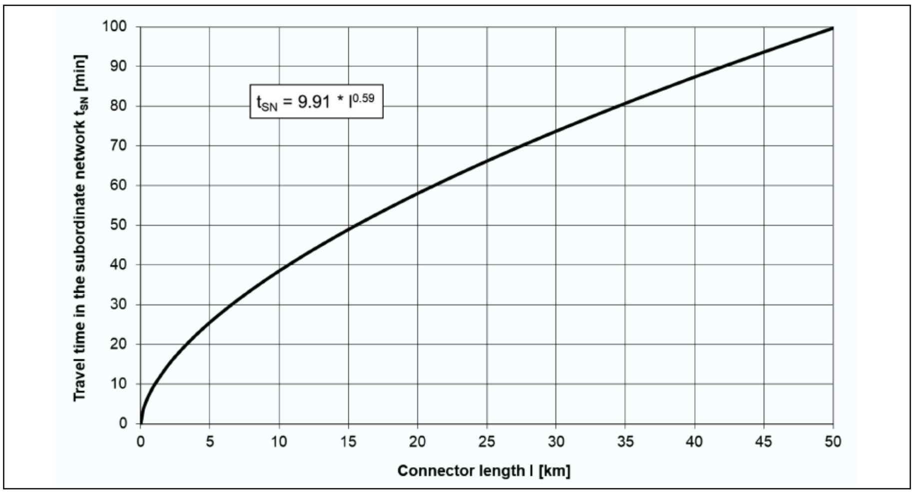


Fig. 25: Travel time t_{SN} on the subordinate network in public transport as a function of the connector length

The origin wait time can be omitted as a component of the connector time if the origin wait time at the first stop is determined individually on the level of origin-destination pairs. In this case, a specific origin wait time is determined for each origin-destination pair from the mean vehicle headway (= service period/service frequency). The function shown in figure 24 can also be used for this purpose.

For a rough estimate of the access time, egress time and origin wait time the values shown in table 22 can be used.

Table 22: Access time, egress time and origin wait time at the first public transport stop of a trip

Headway [min]	$t_{AT}+t_{OTW}$ [min]	t_{ET} [min]
5	7.0	5.0
10	8.0	5.0
15	9.0	5.0
20	10.0	5.0
30	12.0	5.0
40	14.0	5.0
60	16.0	5.0

Travel time in the subordinate public transport network

Travel time t_{SN} on the subordinate public transport network must always be taken into account when the network model does not contain the complete public transport supply, including local services. The travel time t_{SN} is equivalent to the mean travel time to the nearest station with a higher-order public transport supply (rapid transit railway, regional trains, long-distance trains). When determining travel time in the subordinate network, a distinction has to be made between two cases:

- Station is not located within the traffic zone: in this case, the travel time on the subordinate network is a direct result of the direct distance between the centroid of the zone and the station.
- Station is located within the traffic zone: in this case, the travel time on the subordinate network is a result of the mean direct-line length of all locations in the traffic zone to the station. This mean straight line length can be estimated from the area of the traffic zone using the following formula:

$$l = \sqrt{\frac{A}{2 \cdot \pi \cdot n}}$$

where
l = length of the connection [km]
A = area of the traffic zone [km²]
n = number of stations in the traffic zone.

A 2.6.3 Determination of the service levels

The evaluation functions shown above were derived from indicators of 9,600 origin-destination-pairs for car transport and public transport from two transport models:

Transport model for Germany

From this model, around 1,650 origin-destination pairs of connectivity function levels 0 to I were analysed. This transport model contains, as central places, 15 metropolitan regions in Germany and neighbouring countries plus 90 higher-order centres. It comprises the primary road network of 2002 and the range of passenger rail services for the December 2004 to December 2005 timetable period.

Transport model for the Stuttgart region

From this model, around 7,950 origin-destination pairs of connectivity function levels II to IV were analysed. This model contains, as central places, six higher-order centres, 38 middle-order centres, 85 lower-order centres and 313 municipalities with no central place significance. It comprises the entire road network of 2005 and the entire range of public transport services for the December 2003 to December 2004 timetable period.

The values for car transport were obtained using a static model, i.e. the trip time for a specific volume of traffic was determined. The transport models used are 24-hour models, i.e. both demand and capacity refer to a whole day. Thus, in the presentation of the model, the resulting trip time corresponds to the mean trip time of one day. In the transport model for the Stuttgart region, the CR functions were modified in such a way that the trip times corresponded roughly to the conditions at peak traffic hours. This was validated by means of test runs at peak hour for selected origin-destination pairs.

The values for public transport were determined by means of a multi-route search using detailed timetable information.

The LOS curves of direct speed (graphs in figures 27 to 29) are described by the function in figure 26.

The parameters a, b and c of the formula in figure 26 were estimated using the ordinary least square method. . As the number of indicator values varies in each distance class the indicator values were weighted. The resulting curve defines the limit between LOS B and C. Setting the resulting curve as limit between LOS B/C and not as limit between LOS C/D is justified with the argument, that the current average service level in Germany already provides a high quality. The parameters for the other service levels A, C, D and E were then set such that the distance between neighbouring curves were equally spaced . The parameters were determined for three cases.

1. Quality levels for direct speed in car transport

To determine the quality levels for direct speed in car transport (see figure 15), only the direct speeds for cars shown in figure 27 were used when determining the parameters. With the selected distances for the remaining curves, just over 80 % of the origin-destination pairs are in the level A to C range and only 20 % in the D to F range.

2. Quality levels for direct speed in public transport

To determine the quality levels for direct speed in public transport (see figure 16), only the direct speeds for public transport shown in figure 28 were used when determining the parameters. With the selected distances for the remaining curves, which exhibit a greater spread than in car transport, just under 60 % of the origin-destination pairs are in the level A to C range and just under 40 % in the D to F range.

3. Quality levels for direct speed for a comparison of car and public transport

To determine the quality levels of direct speed in a comparison of car and public transport, the direct speeds for cars and public transport were used when determining the parameters. They are shown in figure 29. With the selected spacing for the remaining curves, over 90 % of the origin-destination pairs in car transport are in the level A to C range and just under 10 % are in the D to F range. In public transport, 45 % of the origin-destination pairs achieve levels A to C, with 55 % in the D to F range.

Table 23 shows the parameters for the three cases. With these parameters, it is possible to reproduce the graphs in figures 15 to 17.

Table 23: Parameters for the calculation of the LOS curves of direct speed

Car transport (graph in Figure 15)					
Parameter	**LOS A**	**LOS B**	**LOS C**	**LOS D**	**LOS E**
a	0.1800	0.2100	0.2500	0.3100	0.3900
b	– 0.6760	– 0.6760	– 0.6760	– 0.6760	– 0.6760
c	0.0083	0.0089	0.0096	0.0104	0.0115
Public transport (graph in Figure 16)					
Parameter	**LOS A**	**LOS B**	**LOS C**	**LOS D**	**LOS E**
a	0.1900	0.2200	0.2600	0.3200	0.4000
b	– 0.5000	– 0.5000	– 0.5000	– 0.5000	– 0.5000
c	0.0031	0.0037	0.0044	0.0052	0.0063
Integrated assessment of car and public transport (graph in Figure 17)					
Parameter	**LOS A**	**LOS B**	**LOS C**	**LOS D**	**LOS E**
a	0.1800	0.2100	0.2500	0.3100	0.3900
b	– 0.5900	– 0.5900	– 0.5900	– 0.5900	– 0.5900
c	0.0069	0.0075	0.0082	0.0090	0.0100

To determine the LOS curves of the trip time ratio, a state in which the trip time by public transport is not longer than the trip time by car was selected as quality level A. The regression line derived from the observed values (figure 30) starts in the short-distance zone with a trip time ratio of 1.9 and finishes at 500 kilometres with a trip time ratio of 1.15. A trip time ratio of 1.9 can be observed frequently for short-distance trips, but it cannot really be described as good quality in public transport. For this reason, an increment of 0.6 is applied to the gradation of the other curves in the local range up to 10 km. For a direct distance of 500 km., an increment of 0.15 is chosen. With these parameters, 75 % of the origin-destination pairs are in the A to C range.

The regression curve derived from the car transport indicators for assessing the detour factor (figure 31) starts at 5 kilometres with a detour factor of 1.7 and finishes at 500 kilometres with a detour factor of 1.17. This regression curve was chosen as the boundary between levels B and C. The LOS curve is described by the function in figure 32. The parameters for the calculation of the curves can be taken from table 25.

Figure 33 shows the values for the number of transfers with a logarithmic regression curve. The LOS curves for the number of transfers are described by the function in figure 34.

The regression curve was chosen as the boundary between service quality levels B and C. In the short-distance zone, however, it was corrected such that the curve intersects the Y axis at a value of 0.5. Finally, the remaining curves were determined such that the values for the number of transfers are almost equidistant for one particular distance. In the short-distance zone, the gap between two levels is 0.5 transfers, at 500 kilometres the gap is 0.75 transfers.

Unlike the indicator values for direct speed, the values from the transport model contain the mean number of transfers for all origin-destination pairs between one higher-order centre and another and not only the origin-destination pairs between nearest and the second nearest centres. Since the transport model for Germany only contains the passenger rail services (high-speed ICE trains to semi-fast RE trains), the additional transfers in local transport (bus, light rail, underground, rapid transit) for trips to and from the station are absent. They were taken into account in the data described in a simplified manner by assuming that, as of a direct distance of 100 kilometres, a mean of two additional transfers is necessary. A direct travel option in long-distance transport thus becomes a travel option with two transfers to consider local public transport. In the range up to100 km, a linear rise from 0 to two transfers was assumed.

$$v_{DS,LOS}\,(l_{DD}) = \frac{1}{a \cdot l_{DD}^{\,b} + c}$$

where:

$v_{DS,LOS}$	direct speed [km/h] of a LOS curve
l_{DD}	direct distance [km] between origin and destination
a, b, c	Parameter (see table 23)

Fig. 26: Function for the calculation of the LOS curves of direct speed as a function of the direct distance

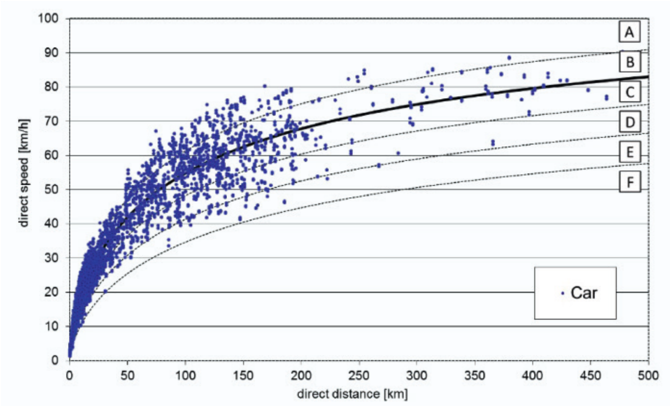


Fig. 27: Observed values of the direct speed for car transport and resultant regression curve

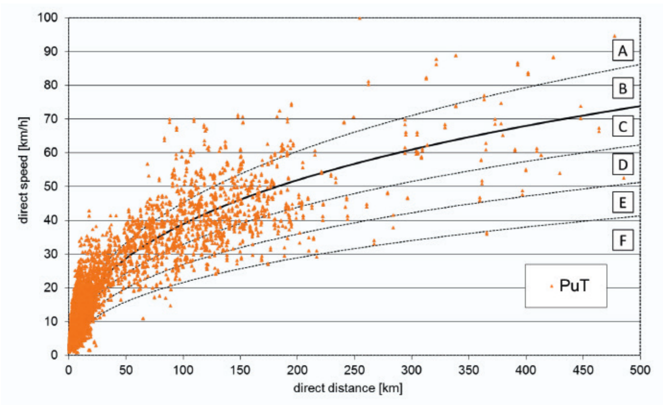


Fig. 28: Observed values of the direct speed for public transport and resultant regression curve

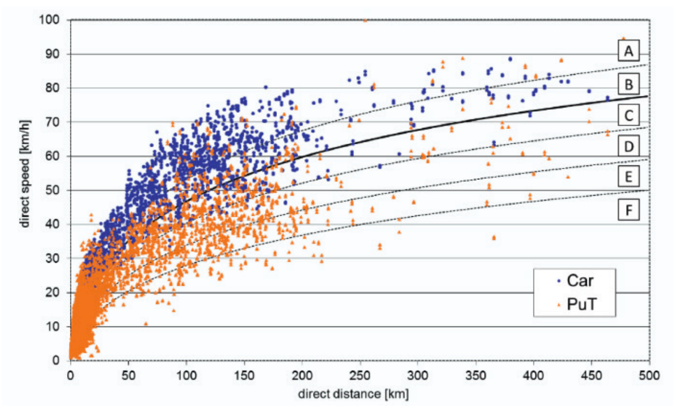


Fig. 29: Observed values of the direct speed for car transport and public transport and resultant regression curve

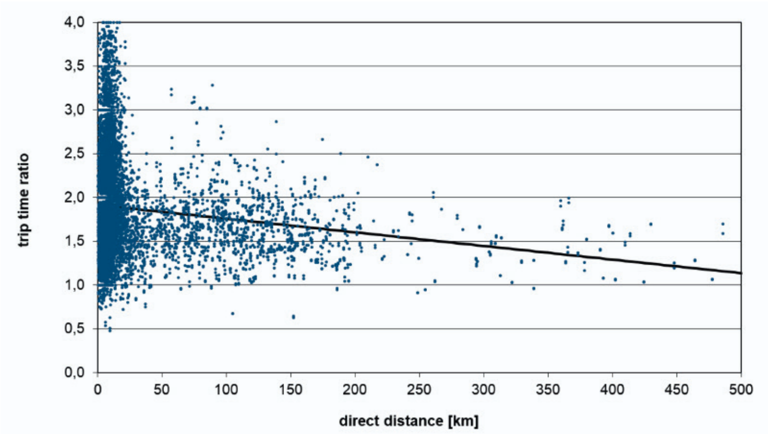


Fig. 30: Observed values of the trip time ratio and resultant regression line

Table 24: Parameters for the calculation of the LOS curves of trip time ratio (graph in Figure 18)

Trip time ratio	LOS A	LOS B	LOS C	LOS D	LOS E
Local range up to 10 km	1.00	1.60	2.20	2.80	3.40
500 km or more	1.00	1.15	1.30	1.45	1.60

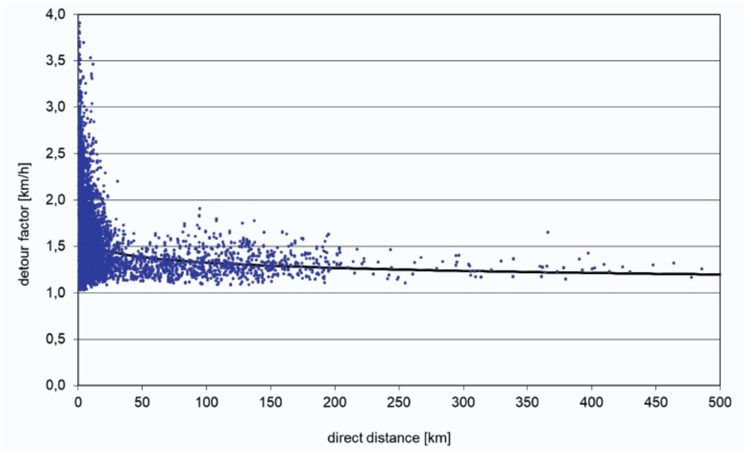


Fig. 31: Observed values of the detour factor for car transport and resultant regression curve

$$DF_{LOS}(l_{DD}) = \frac{10^{a + b \cdot \log10(l_{DD})}}{l_{DD}}$$

where:

DF_{LOS} detour factor of a LOS curve

l_{DD} direct distance [km] between origin and destination

a, b Parameter (see table 25)

Fig. 32: Function for the calculation of the LOS curves of the detour factor as a function of the direct distance

Table 25: Parameters for the calculation of the LOS curves of the detour factor (graph in Figure 19)

Parameter	LOS A	LOS B	LOS C	LOS D	LOS E
a	0.18	0.27	0.37	0.48	0.60
b	0.950	0.925	0.900	0.870	0.840

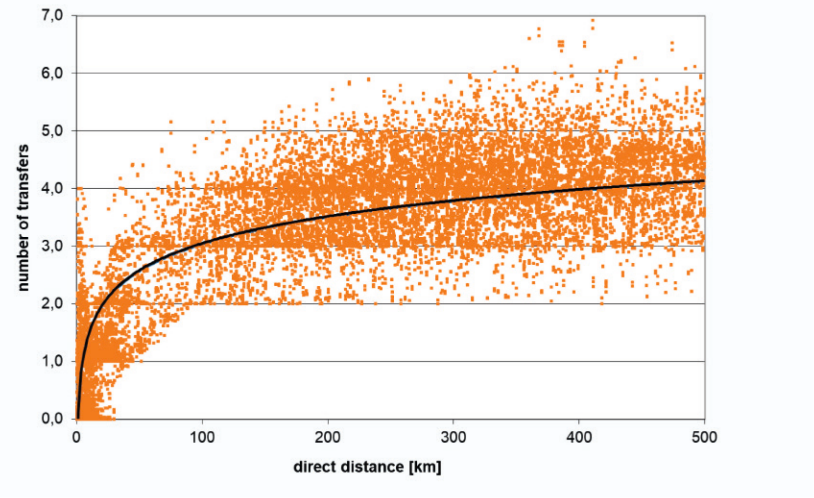


Fig. 33: Observed values of the number of transfers and resultant regression line

$$NT_{LOS}(l_{DD}) = a \cdot \ln(l_{DD}) + b$$

where:

NT_{LOS}	number of transfers of a LOS curve
l_{DD}	direct distance [km] between origin and destination
a, b	Parameter (see table 26)

Fig. 34: Function for the calculation of the LOS curves of the number of transfers as a function of the direct distance

Table 26: Parameters for the calculation of the LOS curves of the number of transfers (graph in Figure 20)

Parameter	LOS A	LOS B	LOS C	LOS D	LOS E
a	0.49	0.53	0.57	0.61	0.65
b	0.00	0.50	1.00	1.50	2.00

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